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ABSTRACT

The model as currently developed consists of three major aspects: contexting, operation, and memory. The contexting aspects of the model are concerned with the higher level cognitive behavior associated with selection of appropriate behavior, maintenance of goals-directedness, and evaluation of completed behaviors. The operational aspects of the model are those behaviors which are performed during the execution of a concept-attainment strategy. Such behavior as creating a search criterion, comparing objects, and presenting concepts were considered operational. The memory component of the model was designed to facilitate the other aspects of the model as well as form the basis for a model of human memory. The memory was divided into three types of storage, each used for a particular purpose. The working memory was a buffer-type memory which received information from the external world and acted as a communication device for the transfer of internally created information. The short-term memory contained all of the information relevant to the attainment of a particular concept. The long-term memory will retain learning strategies and descriptive information necessary to implementation of these strategies and descriptive information necessary to implementation of these strategies. (Author)

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THE DEVELOPMENT OF A COMPUTER MODEL OF THE CONCEPT ATTAINMENT PROCESS: A FINAL REPORT

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THE DEVELOPMENT OF A COMPUTER MODEL OF THE CONCEPT ATTAINMENT PROCESS:

A FINAL REPORT

By Frank B. Baker

Report from the Computer Simulation Project
Frank B. Baker, Principal Investigator

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

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FOREWORD

Contributing to an understanding of children's cognitive learning and improving related educational practices is the goal of the Wisconsin R & D Center. One of the Center's three major research and development programs—Conditions and Processes of Learning—consists of laboratory-type research projects, each concentrating on certain basic organismic or situational determinants of cognitive learning, but all united in the task of providing knowledge which can be utilized in the construction of instructional systems.

One reason that computer modeling has proved to be a valuable approach to gaining knowledge of cognitive processes is that explicit questions are raised—and must be answered—in programming. During the four years he spent modeling the concept attainment process, Professor Baker encountered increasingly complex questions whose answers required, finally, further basic research on learning before he could proceed further in computer technology. His project generated many ideas for gaining knowledge about the psychological processes in concept learning, research ideas to challenge the most inventive psychological experimenter. Although many questions remain to be clarified, the sophisticated model described in this Theoretical Paper represents a major forward thrust in computer technology.

Herbert J. Klausmeier
Director

PREFACE

The pioneering work of the group at the Mellon-Carnegie Institute of Technology, lead by A. Newell and H. A. Simon, had aroused considerable interest in non-numeric computing; however, the lack of readily available list processing languages limited the number of persons able to engage in this activity. In early 1962, Dr. R. K. Lindsay and J. H. Dauwalder, the University of Texas, programmed IPL-V for the Control Data 1604 Computer, thus making it available to the University of Wisconsin. With this new capability at hand, the present author decided to develop computer programs which simulated some aspect of cognitive behavior. Concept attainment was chosen for a number of reasons, paramount of which was that Dr. H. J. Klausmeier and his students at the University of Wisconsin had been working in this area for several years and would provide knowledgeable resource persons; Hunt's book [1962] provided an entry into an unfamiliar literature; and, finally, the concept attainment process appeared to be easy to simulate by means of a computer program.

The first program, which I wrote myself in the fall of 1963, served primarily as a device through which IPL-V was learned. The experience gained from this program convinced me that much could be accomplished and a computer simulation project was written into the original R & D Center proposal. A long-term project in this area was planned during the summer of 1964 with support from a graduate school research grant, and many of the fundamental ideas were developed that summer. Two years were spent in what seemed to be an endless loop of running subjects, writing programs, and redesigning the model. Since the initial program was written, considerable progress has been made; however, we are far from our goal of modeling the processes of human concept attainment.

The purpose of the present final report is threefold. It is first to describe where we currently stand in our research efforts and perhaps provoke some research in the areas we feel are important. The second purpose is to provide others with some insight into the nature and magnitude of the problems a neophyte encounters when developing computer models of cognitive behavior. The third is to illustrate that the "state of the art" is very primitive and much remains to be done.

I would like to emphasize the crucial role played by Mr. Tom Martin, who has programmed all but the first in the long series of programs. He has consistently worked to prevent the programs from becoming what programmers refer to as a "kludge" and has forced me to vastly sharpen my rather fuzzily conceived ideas. Many of my pet schemes have fallen apart and others have been coalesced into vastly improved schemes by his penetrating inquiries. He has also independently developed programs such as MIMIC which are significant contributions to the programming art themselves.

Mr. Alan Pratt collected the first two sets of protocol data and Miss Carin Cooper has collected the remaining five sets. Miss Cooper has also thoroughly reviewed literature in simulation and memory, thus relieving me of a tedious task. Mrs. Eva Bradford conducted the planning experiment and prepared the several levels of program narratives.

Although much remains to be done, this project has been terminated. The two reasons underlying this decision are: First, the "state of the art" limitations in psychological research have been reached, making it impossible to collect the type of data needed for this computer model. Second, my background is in psychometrics, statistics, and computers; but progress in the computer model requires a learning theorist and I did not wish to change my professional orientation to fit the needs of the project. I hope to pursue the linguistic model on an informal basis as the approach is too interesting to drop completely.

F. B. B.

Madison, Wisconsin
1 September 1968

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ABSTRACT

Development of the model described in this final report was begun to obtain a better understanding of the psychological processes underlying human concept attainment. The model has been based upon theoretical grounds, "think-aloud" protocols, and speculations as to the nature of concept attainment. The model developed is embodied in a computer program written in the IPL-V language. The program exists primarily as a device for expressing complex ideas and relationships in a convenient form. The current version of the program, called Mark IV, Mod 2, exhibits a wide range of the behavior observed in the "think aloud" protocols obtained from human subjects.

The model as currently developed consists of three major aspects: contexting, operations, and memory. The contexting aspects of the model are concerned with the higher level cognitive behavior associated with selection of appropriate behavior, maintenance of goal-directedness, and evaluation of completed behaviors. Such functions were labeled *contexting* as the associated computer programs essentially analyze the current situation and define the context within which the operational routines are executed. The operational aspects of the model are those behaviors which are performed during the execution of a concept-attainment strategy. Such behaviors as creating a search criterion, comparing objects, and presenting concepts were considered operational. The memory component of the model was designed to facilitate the other aspects of the model as well as form the basis for a model of human memory. The memory was divided into three types of storage, each used for a particular purpose. The working memory was a buffer-type memory which received information from the external world and acted as a communication device for the transfer of internally created information. The short-term memory contained all of the information relevant to the attainment of a particular concept. The short-term memory was constructed as a "circular memory structure" with a modular format; such a structure enables memory to grow as information is created. The long-term memory will retain learning strategies and descriptive information necessary to implementation of these strategies.

On the basis of the present model it appears that the most fruitful area of future inquiry would be development of a computer model in which the higher level information processing is handled at a verbal level. Such an approach has been labeled a "linguistic model of concept attainment." The salient features of the linguistic approach have been discussed but the corresponding computer programs not written.

Because existing psychological theories and published research do not provide the types of information necessary to further development of the model, a number of areas of fruitful research have been described. For example, the model suggests that the majority of the information processed by human subjects is internally created; hence new techniques are needed to elicit this information.

When compared to earlier versions, the current model has considerable power and seems sophisticated; however, when compared to human concept attainment it is very rudimentary. Hopefully the current model can serve as the basis for further interesting research.

I
INTRODUCTION

GOALS OF THE PROJECT

The fundamental purpose of the present project has been to obtain a better understanding of the psychological processes involved in the attainment of concepts by humans. The particular vehicle through which these understandings have been acquired is that of computer programs which serve as models of the concept attainment process. The use of computer programs as models of cognitive behavior has its origins in the early work of Newell, Shaw, and Simon [1958] who proposed that the "Logic Theorist" program was a model of human problem-solving behavior. Later work by this group and others has resulted in a well established field which is generally called simulation. But because the word *simulation* is widely used in fields other than psychology, most authors currently prefer to use the term *computer models*. The use of computer programs to represent a psychological process involves a number of factors which make the technique extremely valuable. First, because of the small steps by which computers proceed, it is difficult to write programs for something which is ill-defined. Hence, the computer forces one to probe very deeply into a psychological process in order that it be understood well enough to be programmed. Second, the computer program can be manipulated in a number of ways such that it can assist one in understanding the ramifications of the available knowledge about the processes involved. Third, the computer program serves as a repository of the understandings one has acquired up to any given point in time. The ideas are preserved in a language form which is unambiguous and open to study by others. Fourth, in any modeling process one is forced to make assumptions and in a computer program it becomes quite apparent what role these assumptions play in the model. Briefly, the computer serves as an extremely strict task master who forces one to commit to paper what one understands and, more importantly, what one does not understand.

Because one can approach a problem from many points of view the emphasis in a project of this type is a function of the interests of the investigator. In that the present author is firmly committed to "process" psychology rather than S-R psychology, no attempt has been made to study the relation of the model to stimulus materials. The interest here is in *how* a human subject performs the concept attainment task, not in what variables the experimenter can use to manipulate the subject's responses. Using S-R terms, the attempt is to model the intervening variables not the gross S-R connections. In the long term an understanding of the internal processes of a human subject holds considerably more promise for yielding new teaching techniques, classroom materials, etc. than does the traditional S-R approach.

At the present time there appear to be two general approaches to the design of a computer model of cognitive behavior, and these are referred to below as the basic premise approach and the surface approach (see Baker 1967). Under the basic premise approach one postulates a minimum set of operational rules or procedures and then designs a computer program around the successive application of the basic premises or their derivatives to the data presented in the program. The underlying idea is to ascertain how much interesting behavior can be generated by a set of basic premises devised by the investigator. Computer programs which perform pattern recognition [Uhr and Vossler, 1961], the sequence learner of Simon and Kotovsky [1963], and the concept learning system [Hunt, Marin and Stone, 1966] are clearly of this type. Such programs assume that a human has the basic premises and the ability to apply them built in or acquired from past experience, and that the investigator has made a reasonable assumption as to what basic premises are involved. An additional somewhat contradictory assumption usually involved in such programs is that the program, i.e. subject, begins a given computer run with no past experience relative to the data it will process by means of the basic premises, the "clean-slate" assumption. A considerable amount of intelligence, to use the term loosely, is built into the program in regard to how to process the data, but none is built into the program in regard to previous presentations of the data. The resulting behavior of such a program is typically the construction and modification of decision-trees which are completely dependent upon the sequence of data fed into the program.

The surface approach tends to be associated with computer programs based upon human "think-aloud" protocols [Laughery and Gregg, 1962; Johnson, 1964]. Under this approach one attempts to use the protocols to ascertain the gross behavior patterns of humans in a particular problem-solving or learning situation and then to write computer programs which reproduce these gross behaviors. Such programs can usually reproduce the overt behaviors observed in humans, and the computer-generated protocols can be reasonable facsimiles of corresponding human protocols under the same conditions. In contrast to the basic premise approach, the surface approach does not postulate any specific underlying mechanisms; rather it follows some well defined overall plan, such as the concept-attainment strategies of Bruner, Goodnow and Austin [1956]. In addition, it does not make the clean-slate assumption of the former in that knowledge about the data known to be relevant to a particular phenomenon is built into the program.

In that so little is known about how humans solve concept-attainment problems, it was not felt appropriate to make the assumptions necessary for the basic premise approach. In addition, if one follows the basic premise approach, one has very little likelihood of discovering new understandings or obtaining new insights as the total system is based upon a preconceived set of basic premises. However, starting from a surface-type approach one can change the system to match the new understandings acquired as one digs further into the problem rather than being constrained by an artificial set of initial basic premises. Throughout the current project a surface-type approach has been followed, but this is not to say that basic assumptions concerning such things as memory and other facets were not made. However, these assumptions have normally grown out of difficulties encountered within a computer program rather than being preconceived assumptions about the process itself.

In view of the investigator's commitment to the surface approach, a method of attack has been developed which allows one to elicit as much information as possible from the construction of the computer program and at the same time "keep control" of the computer model. The procedure followed is given in the paragraphs below.

One begins with a computer program which corresponds to the behavior of an intelligent, experienced subject performing a particular type of concept-attainment problem after having had considerable practice. One then slowly builds into the model various types of behavior which are not as efficient as those used by the experienced subject and thus degrades the performance of the computer program. What one attempts to do is work backwards toward a computer program which will be as inefficient and stumbling as a person attempting the problem for the first time. By deliberately introducing a particular change into the computer program and then observing how the subject's performance of the task has been degraded by that change, one gets an understanding of the ramifications of each change made to the computer model. Such an approach is somewhat at variance with a large number of other simulation projects which have attempted to write a computer program for a subject who is initially very inefficient and inept at solving a problem and then improves to the performance level of an experienced subject. The latter approach appeared to the present author to be a more difficult task as at the current state of knowledge one does not have a good grasp of what causes the subject's inefficient, inept performance. It seemed much more appropriate to start from the experienced subject and slowly work backwards with a good understanding of each backward step and its effects upon performance. Thus, the amount of variability in the behavior built into the computer program is a function of our understanding of the concept attainment process. Eventually the computer program would become as inefficient as a human attempting a problem for the first time, but at that point one would understand the reasons for this level of performance and the processes by which a subject improves his performance over a sequence of problems. Then, one would expect to have an extremely good model of the concept-attainment process which could serve as a guideline for further educational-psychological investigations in the classroom.

The so-called backward approach has proved to be very feasible and quite rewarding in terms of the understandings of the concept-attainment process we have been able to obtain. The backward approach allows one to continually tie the computer model back to actual subject behavior and to insure that what has been built into the computer program does in some manner represent actual subject behavior. It does not imply that the mechanisms are true representations of the subject's internal processes; however, the external behavior of the program can be observed in subject behavior.

THE EXPERIMENTAL SITUATION TO BE MODELED

The type of experimental situation for which a computer model has been developed is that described by Bruner, Goodnow and Austin [1956] and used extensively by psychologists. In such experiments, a subject is seated before a board containing a number of objects. Each object contains m dimensions and each dimension has n values; thus a complete board has n^m different objects. The experimenter explains to the subject that the objects can be divided into two mutually exclusive groups, members and nonmembers of the set defined by a classification rule (concept) consisting of a particular combination of dimension values. The experimenter designates an object (the focus object) as a member of the set. The subject's task is to discover the classification rule by choosing objects and having the experimenter designate their set membership. When the subject feels he knows the underlying classification rule, he tells it to the experimenter. If the rule is correct, it is assumed that the concept has been attained; if not, the subject continues until he can present the correct classification rule.

Bruner, Goodnow and Austin [1956] identified and labeled a number of strategies which subjects employed in this experimental situation and two, the "conservative focusing" and "wholist," are of interest to the present paper. Using the conservative focusing strategy, a subject chooses an object from the board identical to the focus object except for one dimension whose value has been varied. When such an object is designated as a member of the set, a "yes" object, he knows that the dimension is not included in the classification rule, hence is irrelevant. If the object so chosen is designated as not being a member of the set, a "no" object, he knows that the dimension is relevant, the dimension value of the focus object is included in the classification rule. In the conservative focusing strategy, the subject varies one dimension at a time and systematically checks each of the m possible dimensions. Thus, the minimum number of object choices to attain the concept is m, the number of dimensions.

Using the wholist strategy, the subject determines the classification rule through the intersection of all objects designated as members of the set by the experimenter. If an object chosen by the subject is designated as a member of the set, it will have certain dimension values in common with the focus object. Thus, a "yes" object is of value to the subject and a "no" object is of no value under this strategy. The subject continues developing the intersection of a series of "yes" objects and the focus object until he feels he knows the concept. Typically, under this strategy, subject will present a concept for designation by the experimenter after each "yes" object.

Although both strategies had a concept attainment, they differ in two major aspects. First, the method for choosing objects under the conservative focusing strategy is well defined and quite obvious to the observer, whereas under the wholist strategy the object choice mechanism is not so clearly observable. Second, the meaning of a "yes" and "no" designation of an object choice is reversed in the two strategies. In the conservative focusing strategy a "no" is the desired designation, and in the "wholist" a "yes" is the desired designation. Programs for both of these strategies were developed in the present project, but the primary emphasis has been upon the conservative focusing strategy.

DEVELOPMENT OF THE COMPUTER MODEL

The books by Bruner, Goodnow, and Austin [1956], Miller, Galanter and Pribram [1960], and Hunt [1962] and journal articles on the concept-attainment process were read to develop some understanding of what others had done in the concept-attainment area. On the basis of this initial investigation and the author's own intuitive understanding of how he would solve a concept-attainment problem, a computer program was written which would "simulate" concept attainment. The initial computer program called Mark I, Mod O was published in early 1964 [Baker, 1964]. On the basis of this program protocols were collected to ascertain how sophomore subjects from the University of Wisconsin, who had not previously seen this kind of problem, would solve it. The "think-aloud" procedure was used to collect data which was then analyzed by the project staff. On the basis of the analysis of the protocols, it was determined that the majority of the subjects very rapidly developed a conservative focusing strategy. Therefore, the computer program was redesigned to incorporate a conservative focusing strategy. A computer program to model a specific subject has not been developed; rather many subjects, both male and females, have been used and the "normative" behavior of the subjects was modeled.

THINK-ALOUD PROTOCOLS

The data gathering device used throughout the project has been the think-aloud protocol. As the experiment is being run, the subjects verbalize what they are doing and why they are doing it. Such a procedure has been a standard practice among those developing simulation programs even though it is not held in high esteem in many psychological circles. It was found quite early that the raw protocols were not very rich in information and a modified system was adopted in which the experimenter asked preplanned questions at certain points within the problem. The questions arose from the computer program and were designed to help fill the gaps in the program. For example, at one point the interest was in whether subjects remembered specific object choices, thus after the fifth object choice, they were asked to identify the second object chosen. Such information would not be yielded by the usual protocols, yet is easily obtainable through selective interrogation. A total of seven sets of protocol-gathering sessions, each involving five male and five female subjects were conducted, tape recorded, and reproduced in mimeographed form. In each of these seven runs a different set of questions was used to aid in development of the computer program.

Analysis of the early protocols revealed that the materials used by Bruner et al. [1956] and Klausmeier, Harris, and Wiersma [1964] involved psychologically dependent dimensions; subjects were unable to treat shape as an independent dimension. To overcome this problem new materials, consisting of animals whose dimensions were ears (long-short), neck (long-short), body (thin-fat), color (yellow-blue-brown) and tail (straight-bent-curly) were devised. Figure 1 presents one of the 72 possible animal configurations. Two of the dimensions were three-valued to overcome the artificiality of all binary valued dimensions. The new materials proved very successful and were used throughout the remainder of the project.

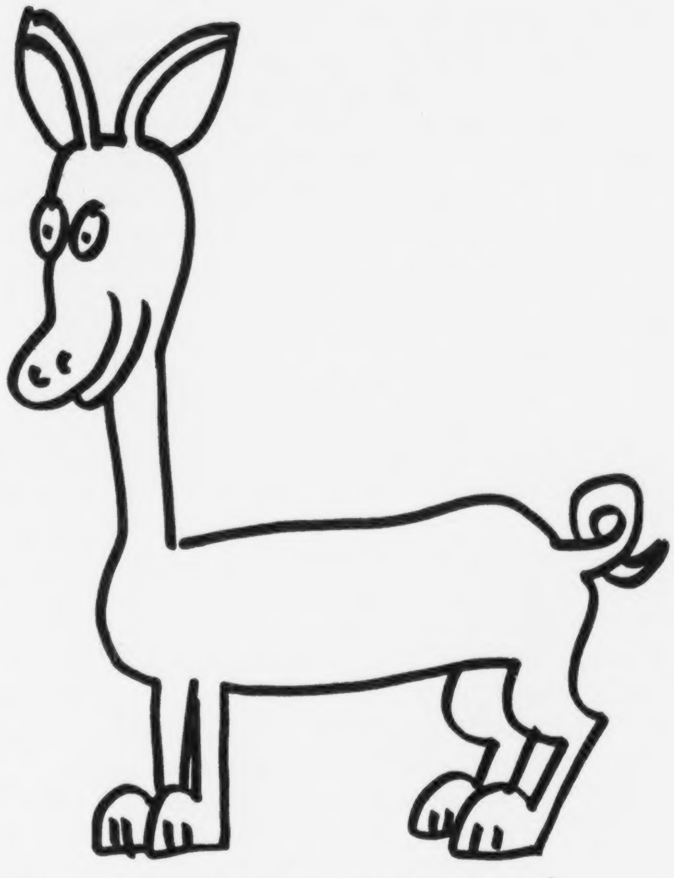

Fig. 1. One of the 72 Possible Animal Configurations

UTILIZING THE COMPUTER PROGRAMS

After writing a computer program to model the behavior of the subjects in the concept-attainment task, one spends a considerable amount of time analyzing the computer program itself in order to reduce it to a simple structure. It is very easy to become trapped with a computer program which is so complex and clumsy that it does not lend itself to the continual modification required by the so-called backward approach. Therefore, extreme care has been exercised to avoid a situation which requires periodically starting from the beginning.

A vast amount of effort has been devoted to the mechanics of the computer program itself in order to facilitate the modeling process. Data representation schemes, methods of communication within the computer program, and methods of executing the computer programs representing various types of behavior have been devised. What has been developed is essentially a small computer programming system within which a model of the concept-attainment process may be developed. Strange as it may seem, much of the understanding of the concept-attainment process has arisen out of attempts to develop a systematic computer program for use in the modeling process.

After a particular version of the computer program has been reanalyzed, rewritten, and polished to the point where it is a reasonable representation of our current understanding of the concept-attainment process, considerable effort is devoted to looking at the points where insufficient information exists. Questions are then devised to be asked during the next protocol run which will help clarify the particular point of concern. Thus, a large feedback loop exists in which attention shifts from subjects to computer program, to subjects, and then to the computer program again.

SUMMARY

The goal of the present project was to develop a model of the various cognitive processes involved in human concept attainment, and it was toward the end of understanding these processes that the above procedures were directed. A lesser interest was in a computer program which would be an interesting tool in developing further understandings and insights into the concept-attainment process. There was little concern with developing a computer program which could generate large amounts of interesting data for later analysis or reporting in "See what our computer program can do" fashion as has been so typical of past efforts. The computer program is considered to be a repository of ideas about the processes involved in concept attainment expressed in computer programs in the IPL-V language. Recording ideas in this way may seem peculiar, but in a problem as complex as concept attainment it is virtually impossible to verbally represent all of the facets involved.

II

A COMPUTER MODEL OF THE CONCEPT-ATTAINMENT PROCESS: CASE MARK IV, MOD 2

INTRODUCTION

In this chapter several levels of description of the most recent model of the concept-attainment process produced by the project staff are provided. One level will be rather gross so that the internal structure of the program can be seen without the clutter of mechanical details. The second will be at the subroutine level to provide the reader with some appreciation of the formidable problems faced in implementing a computer model of cognitive behavior. In order to present the latter level it is necessary to discuss various mechanical details underlying the actual computer program. A full understanding of the model can only be obtained through a detailed study of the listing of the computer program which is presented in Appendix B. Although the computer program has been written in IPL-V [Newell, et al., 1964], a serious attempt has been made to describe the program without involving more than a bare minimum of the IPL-V language.

Assumptions

In order to program the present model a certain number of assumptions were made. The foremost of those was that the subject's perceptual processes are perfect; thus, the processes of perception were ignored. Even though a large proportion of the errors made in the concept-attainment process can be attributed to perceptual errors of one type or another they were not modeled. Secondly, the assumption has been made that memory is perfect; i.e., the computer model does not contain any forgetting processes. At some later point in time, it is anticipated that both decay and interference-type forgetting can be introduced into the computer program, but at the current time such mechanisms would obscure other more crucial aspects.

A major effort in the development of this computer model has been devoted to eliminating the necessity for large numbers of input parameters and prestored information. At the current time only three types of information are prestored for use by the computer program. One of these is the dominant dimension values. Analysis of the initial protocols indicated that subjects possess a preference for certain dimensions and certain values of these dimensions. For example, it was found that female subjects invariably will utilize the dimension of color rather early in the solution of their problem, and certain people will prefer yellow over blue or brown. Built into the computer program is a selection device based upon probability values assigned to the dimensions and to their values. However, this information is used only at one point in the computer program and is not crucially involved in many of the psychological processes. It should be noted, however, that considerable variability in behavior can be accounted for by these dominance values. Three constants have also been prestored in the program which help mechanize certain types of within-problem variability. These constants are associated with the number of dimensions that a subject will use during a particular concept-attainment problem and the number of dimensions he will add to his initial approach when he discovers that it has not worked. The third and final prestored parameter is one known as an awareness factor. The protocols have indicated that many subjects use less than the total number of dimensions in their problem solution and that some of these people are aware of the fact that they are using less, others are not. Therefore, a flag is used to indicate whether the subject is aware that he is using less than the full number of dimensions in his approach to the problem. Other than these three types of information, all data gained by the subject is stored in memory as it is either received from the external world or created by the subject himself.

Representing Cognitive Process

In order to describe the computer model of the concept-attainment process it is necessary to explain a certain amount of symbolic representation used internally by the computer program. In that this project was influenced quite heavily by the earlier work of Bruner et al. [1956] and that of Miller, Galanter and Pribram [1960], the program is built around the idea of strategies, and the mechanics of the program are designed to implement strategies or plans. Quite early in the project it was discovered that the programming system must have the capability to minimize the impact of significant changes and simultaneously to maximize the ability to make such changes. Therefore, a pseudocode system and an interpreter, both using IPL-V, were developed as a reasonable solution to this technological problem [Baker & Martin, 1965a].

The strategy consists of an IPL-V list containing symbols representing routines which are to be performed as well as local symbols which indicate branches in the program. These lists, however, do not contain any IPL-V primitives and are not executable IPL-V programs. Table 1 contains a list of symbols representing a typical concept-learning strategy.

Each symbol on the list can be the name of a list of symbols; this representational form can be carried to any depth desired. These symbols are referred to as pseudocodes as they are merely abstract representations of psychological processes. In the current program there are three levels in the list structure which constitute a learning strategy. The highest level, the S level, is essentially an executive level description of the overall learning strategy. The second level consists of major procedures, the Z or D routines, which perform salient tasks such as hypothesis generation. The third and lowest level are the P's and Q's which are executed to perform the information-processing tasks necessary for concept attainment. The P's and Q's are contained within the Z's and D's and the Z's and D's are contained within S. Throughout the list structure a distinction is maintained between programs which do things, the Z's and P's, and those which provide decision-making information, the D's and the Q's. The former are analogous to the O routines and the latter to the T routines in TOTE units [Miller et al., 1960]. Only the lowest level routines can result in the direct execution of subroutine coded in IPL-V, and the higher levels serve only to hold together various combinations of executable routines. The underlying principle is that the P's and Q's are the basic information processing capabilities possessed by a subject, and various tasks are performed by assembling the proper sequence of P's and Q's into the Z's or D's. The Z's and D's are then assembled into the strategy list (S). Such a strategy list is then executed by a special purpose interpreter [Baker & Martin, 1965a] which works its way through this list structure until it finds a routine which is executable, namely at the lowest P or Q level. It executes the routine and then returns up to the next higher level to ascertain the next executable routine. Fundamentally the interpreter is an ordinary IPL-V recursive program which calls upon itself to work its way up and down the branches of the list structure representing the learning processes.

Table 1. Symbolic Representation of the Conservative Focusing Strategy List as Used in Mark IV, Mod 2

S2	9-0	
	Z0	Process focus information
	C21	Create procedure Z7
	Z7	Establish search criterion
	D4	Determine whether subject should proceed
	9-2	No, error exit
9-1	Z1	Construct search criterion
	Z2	Select object from external environment
	C37	Create decision procedure D1
	D0	Determine whether object selected meets subject's needs
	9-1	No
	Z3	Experimenter designates set membership of the object choice
	C38	Create routine Z4
	Z4	Process information gained through object designation
	D1	Determine whether a concept can be presented
	9-1	No
	Z5	Form a concept
	Z8	Experimenter designation of correctness of concept
	C22	Construct procedure Z6
	Z6	Subject's reaction to designation of concept
	D3	Determine correctness of concept
	9-1	No
	0 0	Yes
9-2	X21	Error exit
	0 0	

Memory Structure

Quite early in the development of the concept attainment program, it was determined that memory plays a crucial role in the concept-attainment process, and it was necessary to design a rudimentary model of memory. Under this model, memory was divided into three major aspects: working memory (WM) which is a temporary, buffer-type memory; short-term memory (STM) in which all information relative to a given problem solution is stored; and long-term memory (LTM) where the subject stores information which is to be retained over a longer period of time. Thus, the partitioning of memory is a function of the duration of time over which the information is to be retained. Such a three-part memory does not correspond directly to the memory model ordinarily used by psychologists, which involves only a short-term memory and a long-term memory. Most of the functions of what was called short-term memory are embodied in their long-term memory. However, investigation of the protocols seems to indicate that subjects retain information about a problem only long enough to solve that particular problem and then do some recoding to save the salient features over longer periods of time. Therefore, it was suggested that there is a distinction between short-term and long-term memory which psychologists do not normally recognize.

The short-term and long-term memories have a highly interconnected net structure which is developed by the program as information is acquired. The dynamic nature of the memory structure is an important feature of the three-level model, but discussion of the actual mechanics of this system will be deferred to a later section in the present paper.

The Contexting Hierarchy

The internal organization of computer models constructed under either the basic premise or the surface approach is focused upon implementing a rather specific psychological phenomena and does not take into direct account a higher level of cognitive behavior, namely that which in some sense directs, maintains, and evaluates the overall problem-solving or learning behavior of a human subject.

In order to clarify this issue, let us briefly examine a problem-solving or learning experiment as it is usually conducted. In such an experiment there is a fairly typical sequence of events which transpire in roughly the following order:

(a) The experimenter explains the nature of the task, the characteristics of the experimental materials, and the types of products the subject is to produce.
(b) The subject relates the given information to what he already knows.
(c) Once the subject has assimilated the information to his own satisfaction, he embarks upon an approach to the task which is resplendent with errors and inappropriate decisions; false strategies, and unproductive acts; nonetheless, his behavior is goal directed.
(d) The subject is able to evaluate, in some sense, how well he is doing by means of both internal and external clues.
(e) With sufficient experience on the same task, the subject is usually able to modify his own behavior to the point where he becomes proficient at the task and his once clumsy performance becomes smooth and effortless.

In that such a pattern of behavior is essentially independent of the particular task, it is very difficult, for the present author at least, to conceive of a realistic model of human behavior whose internal organization does not provide for some form of a central executive to account for this communality. The relevant issue is the form of this central executive and the internal organization of a computer program necessary to represent it in a computer model of cognitive behavior. Unfortunately, it is extremely difficult to obtain direct evidence from either protocols or psychological experiments from which to develop a model of such a central executive. In addition, how to create one is not obvious; as Newell [1962] said, "In attempting to create such a central organization we found—as we had in the problem of communicating strategies—that we had no concepts and no formal language to discuss the variety of results and their uses [p. 410]."

In earlier editions of the program such a central executive was confounded with the strategy list; however in the current version, the supervisory or executive aspects of the program have been separated from those of the operational aspects. The C routines represent this executive function and constitute a hierarchy of control whose role changes as a function of the stage of the task performance. Because the function of the supervisory program changes often, the term *contexter* is probably more appropriate for these routines than *central executive*, which carries an unwarranted connotation of a single supervisory program. Although the role of a contexter is a function of the situation in which it operates, there is nonetheless an underlying communality throughout all levels of contexters which can be described by a series of questions which a context routine attempts to answer; i.e., (a) What is the current situation? (b) What does it mean? (c) What could be done? and (d) What will be done? Thus, whether the contexter is dealing with a gross overall plan of approach to a task, or to some small operation within a subtask, the fundamental framework of a contexter routine is invariant; what varies is the situation in which the contexter functions and the procedures by which it attempts to answer these questions. It is worth noting that the definition of the current situation includes not only the available data but also the sequence of behaviors leading up to the present point in time. The result of calling a contexter routine is to execute some behavior for which an appropriate context has been established.

A contexter may be said to create a plan or a strategy for behavior. At high levels in the model, it creates a plan for overall behavior such as the S list, and at low levels it creates plans for very specific actions such as P lists. Such a planning hierarchy was first envisioned by Miller, Galanter, and Pribram [1960] when they suggested the existence of plans which create plans. Because of the rather complex interrelationship between the contexting programs and the strategy lists, a detailed discussion is deferred to a description of the actual computer program itself.

THE CURRENT PROGRAM—MARK IV, MOD 2

The preceding paragraphs have acquainted the reader with some of the major considerations in the design of the simulation program; the overall picture of the operation in the current version of the computer model of concept-attainment is as follows. First, the experimenter verbally describes the experimental situation to the subject—what the experiment is about, what the board looks like, the dimensions on the board, and their values. The experimenter also indicates to the subject that he is to select objects which the experimenter will designate as to their set membership. When the subject feels he understands the concept, he is to present it to the experimenter for designation. Upon receipt of the instructions, the subject proceeds to try to attain the concept. The computer program is set up with an initialization phase which utilizes the subject's past experience and his particular characteristics, namely some of the constants mentioned earlier and the dominance values, to establish an initial set of conditions within the subject. After completing this initialization phase, the computer program creates a search criterion and locates an object in the external environment which it also feels is a member of the set. If the object found meets the requirements of the subject's search criterion, it is presented to the experimenter for designation. After receiving the designation, the subject processes the meaning of *yes* or *no* in light of his own understanding of the problem. If the subject feels he can present a concept he proceeds. However, in most cases the subject takes several object choices before he has enough information available to decide whether or not he understands the concept. Therefore, at this stage, the computer program returns to creating a new criterion and locates other objects from the board visible to the subject. The final phase of the program occurs when the subject feels he has enough information to present the experimenter with a concept for designation. If it is incorrect, the subject then has to construct a reaction to this incorrect designation and return to the first phase in which he searches for additional objects that will enable him to ascertain the correct concept. If the concept is correct, the problem is terminated and the subject then evaluates what he has accomplished during the course of this particular problem. So much for an overview of the concept-attainment process. Let us now turn our attention to a discussion of the flow chart which is given in Figure 2.

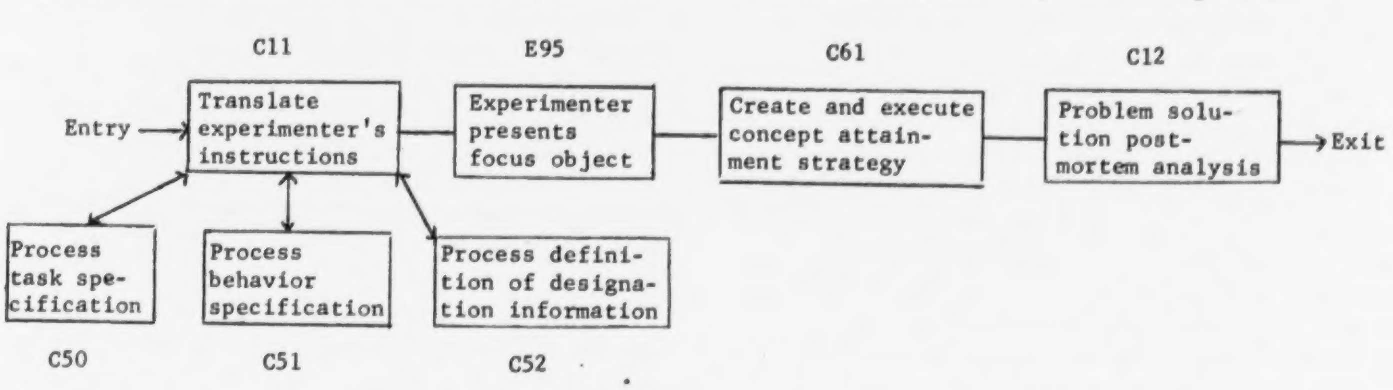
C11
E95
C61
C12
Entry
Translate experimenter's instructions
Experimenter presents focus object
Create and execute concept attainment strategy
Problem solution postmortem analysis
Exit
Process task specification
Process behavior specification
Process definition of designation information
C50
C51
C52

Fig. 2. Flow Chart of the High Level Contexter List S3

This flow chart will be discussed in terms of the particular routines which are in the flow chart. No attempt to go into all the programming or mechanical details is made, but a verbal description of what occurs within the program is given and any relevant assumptions which have been made by the particular program are indicated. The highest level program list in the computer model is called S3 which is the high level contexting list. This program essentially contains a gross description of what is to occur in the attainment of a concept and consists of four computer programs: C11, which creates a tentative strategy from the experimenter's instructions; E95 in which the experimenter presents the focus object to the subject; C61 which creates and executes a strategy phase-by-phase until the concept is finally attained; and C12, a problem solution postmortem analysis in which the subject ties together what he has done into a workable learning strategy for future use. It should be noted that C11, C61, and C12 are contexting-type routines.

The messages from the experimenter explaining the problem to be solved have been coded in terms of attributes and particular attribute values which essentially describe major behaviors; such coding gets around the syntactical-semantic analysis problems normally associated with translating English language into a computer program. This particular problem was completely by-passed because it is a major research project in itself. Rather, experimenter messages have been created describing behavior in terms of attributes and values so that the long-term memory can be searched to see whether other behaviors carrying this description are available for assembling into a strategy. Such an approach is rather crude, but it enables a form of translation of instructions to behavior to be introduced into the model.

The C11 routine accomplishes the translation of experimenter messages to a description of a rough skeleton learning strategy. In the first problem attempted by a subject, the C11 routine creates a skeleton strategy list which describes the gross behaviors necessary to attack this concept-attainment problem. In subsequent problems, C11 searches the long-term memory to obtain a strategy list from a previous problem which can be utilized as the approach to the problem. C11 consists of three major subroutines, each one associated with a different type of message which can come from the experimenter. The first subroutine, called C50, creates a problem list, indicates what the problem is, and stores descriptive information such as which problem it is. The second subroutine, called C51, creates a description of a skeleton strategy for solving the problem. The skeleton strategy does not include all of the behaviors necessary to attain the concept, but stores the major framework of the experimental situation contained in the experimenter's messages. The third major subroutine, C52, is designed to store specific types of information which the experimenter presents, such as that he will designate set membership of an object by the words *yes* and *no*. Thus, C11 takes in a particular message from the experimenter's verbal instructions and translates it into descriptions of particular behaviors which the subject must perform in order to attain a concept. Which of the three C50 routines used is a function of the message that has been received from the experimenter, and there are decision processes within C11 enabling the program to call the proper subroutine for a given message. There are two major outputs of the C11 routine, one of which is the beginning of the short-term memory structure which the program will grow during its solution of the concept-attainment problem. The second is a skeleton strategy list containing symbols representing the major procedures within the concept-attainment task as indicated by the experimenter. The initial point of the short-term memory, the symbol L100, represents the problem and carries the description of the problem obtained from the experimenter messages. The skeleton strategy list contains symbols which are not executable routines at this point, but are merely symbols which hold descriptions of the kinds of behaviors necessary to accomplish the task. If the subject has previously attained a concept, rather than constructing a skeleton strategy C11 locates the recently used strategy in long-term memory and places its name in memory.

When C11 has been completed the subject knows in a general way how he is to perform the concept-attainment task. To specify a particular concept-attainment task, the experimenter must identify the focus object, which is an exemplar of an object belonging to the set defined by the unknown classification rule. Routine E95 performs this function by placing the name of the focus object in the subject's working memory. The name of the focus object is accompanied by descriptive information indicating the set membership of the focus object. Upon completion of this action, control of the program returns to the subject.

The major contexting routine in the current program follows E95 and is called C61. At the time this routine is executed, the short-term memory contains the symbol L100 which

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represents the problem to be solved, and the contents of the working memory are either the name of the skeleton strategy or a previously developed strategy. The routine checks a flag to determine whether this is the first problem it has solved or not. If it is not the first problem, C61 assumes that the contents of working memory are a fully developed strategy which is given to the interpreter for execution. If it is the first problem, the program must translate the description of the skeleton strategy created by C11 into executable behavior. The C61 routine creates a symbol for the strategy list and then creates a symbol for the first phase of the strategy. Having created a phase symbol, it then searches long-term memory to find a routine whose behavioral description matches that of the first routine on the skeleton strategy list. In this situation it will be routine Z0 which receives the focus object and its designation from the experimenter and stores them on the problem list. Because Z0 receives information from the external environment, it is followed by a contexting routine. It should be noted that one of the rules of the computer program is that a contexter routine follows whenever information is received from the external world. In this case contexter C21 is inserted on the phase list after routine Z0. The function of the contexter C21 is to create routine Z7 which uses the focus object and characteristics of the subject to establish the initial working hypothesis. Because C21 will create routine Z7 at execution time, the C61 contexter will place a symbol on the phase list to hold a position for this future routine. The symbol for Z7 is followed by routine D4 whose function is to determine whether the information yielded by Z7 is adequate. If it is adequate, the next phase can be constructed; if inadequate, C61 will have to attempt to create a new Phase 1. The basic process embodied in C61 is one which creates a phase list containing routines matching the behaviors described by the experimenter. Routines processing information from the external world are followed by decision routines which ask "Can the strategy proceed?" These decision routines also terminate the phase list. Thus C61 creates a phase, executes it, and, if it receives the go-ahead, creates the next segment of behavior.

Phase 2 created by C61 is the object-choice phase, consisting of routine Z1 which creates a search criterion by varying one or more dimension values of the working hypothesis, routine Z2 which chooses an object from the board, C37 which establishes the test conditions for the last routine, D0, which ascertains whether or not the object choice meets the subject's needs. If it does, C61 continues to Phase 3; if not it returns to Phase 2 and re-executes it.

Phase 3 is the experimenter designation of the object phase, containing routine Z3 which presents the object to the experimenter for designation and routine C38, a contexter that establishes the routine Z4. The procedure Z4 processes the information provided by the experimenter's designation of the set membership of the object chosen. Following the logic of the conservative-focusing strategy, Z4 flags the dimension or the dimension value as relevant or irrelevant, depending upon whether or not the object was designated *yes* or *no*. The last routine in Phase 3 is routine D1 which ascertains whether or not a concept can be presented at the current point. D1 checks each of the dimensions of the working hypothesis and determines whether the subject considers them relevant, irrelevant, or untested. If all dimensions have been flagged by Z4 as either relevant or irrelevant, sufficient information is available for the subject to present a concept to the experimenter. But D1 is also conditioned if the subject is using less than the total number of dimensions and all those he is working with have been flagged. If a concept can be presented, Phase 4 is entered. If not, the program returns to Phase 2 and executes Phases 2 and 3 over again.

Phase 4, which is the final phase, consists of procedures Z5, Z8, C22, Z6, and D3. In routine Z5 the subject searches the dimension values of the working hypothesis for those values which are relevant and from the relevant dimension values creates a concept, i.e., a list of dimension values which it believes defines the classification rule. The next routine is Z8 which presents this concept to the experimenter for his designation. Upon designation, a contexting routine, C22, is executed because Z8 brought in information from the external world. C22 is very similar to C38 in that it will create a situationally dependent routine Z6 for utilizing the information provided by the designation of a concept; Z6 is only created if the concept is incorrect as a subject then has to ascertain what is wrong with his prior behavior. Z6 primarily looks for dimensions which have not been involved in the concept itself. In other words, it looks through the dimension and dimension values of the focus object searching for untested dimensions. If it finds untested dimensions, it then adds them to the working hypothesis list. For example, if a subject initially only used three out of the five possible dimensions, Z6 will add one or more dimensions as a function of the number of untested dimensions available and the value of the parameter K97 which specifies how many dimensions are to be added. If Z6 discovers that all the dimensions have been flagged and the subject still has not attained the concept, it then assumes that he has misflagged a dimension. Instead of adding untested dimensions to the working hypothesis, it will unmark dimensions on the working hypothesis list so that a new search criterion will include those which have been used in the past. The last routine in Phase 4 is routine D3 which ascertains whether or not the subject should continue to attempt the problem. The phase lists created by C61 are presented in Table 2.

Upon the completion of Phase 4, C61 realizes it has a list of executable routines for all the behaviors from creating a search criterion to testing the concept; therefore, it treats this list as a substrategy, i.e., the strategy is complete except for the initilization phase, but because nothing has to be reinitialized, this subprogram can be executed as if it were a total strategy. Hence, if the concept were incorrect, the substrategy would be executed until the concept is attained.

All four phases created and executed by C61 from the skeleton strategy list have the same general structure. There are one or more major procedures at the Z level. When information is received from the external world, a contexter routine creates a situationally dependent routine to determine the meaning of the external information. The final routine in each phase is a D routine which essentially asks whether the subject can proceed or must return to the object selection phase to get further information.

In review, C61 proceeds step-by-step and performs the behaviors indicated by the skeleton strategy as being involved in the concept-attainment process. It picks its routines from long-term memory by comparing the description of what needs to be done with the description of the capabilities of routines stored away in long-term memory. Each phase is created to handle logical units of behavior within the concept-attainment process, and the phase is given to the interpreter for execution. If progress can be made, C61 will move on to create and execute the next phase within the problem, and repeat this process until it can present a concept. If, upon completion of Phase 4, the concept is correct, the program is terminated; if incorrect, C61 treats what it has already created as a strategy and executes the strategy until a concept has been attained.

The routine following the successful completion of a strategy is a postmortem analysis routine called C12. Because the model has not progressed beyond the within-problem analysis stage, this aspect of the process has not received more than cursory attention. At the current time the task of C12 is to tie together the total strategy which has been created rather piecemeal by C61. It places symbols representing Phases 1, 2, 3, and 4 all in a common strategy list and puts links from each of the phases to Phase 2. It was intended to have C12 do an analysis of the execution of the program, ascertaining whether there were unnecessary behaviors and smoothing out a successful strategy. C12 also stores the successful strategy on the long-term memory so that it can be used by C11 when a subsequent problem is attempted.

The computer program described above attempts to model the salient features of a subject performing a concept-attainment task. The initial stages are quite slow because experimenter instructions must be understood, a rough idea of how to proceed must be constructed, and the subject proceeds step-by-step. Once the full process has been gone through the pace quickens since the subject repeats behaviors established during the early phases, thus eliminating most of the C61 level contexting previously required. Hopefully what has been developed is a reasonable framework within which investigations of the concept-attainment process can continue.

THE STRUCTURAL DETAILS OF THE COMPUTER PROGRAM

Symbolic Representation of Behavior

In order to present a detailed discussion of how the computer program attains concepts, it is necessary to elaborate further upon the internal structure of the computer program. Attention will be given to the representational scheme for subroutines, the attribute system, and the memory structure.

Let us examine one process within the strategy list, routine P61 which appears in procedure Z0. The list of symbols representing the routine P61 is given in Table 3. The symbol P61 represents a nonexecutable routine whose function is to hold the description of the executable routine P60. Thus, the P61 symbol is a pseudocode whose description defines the context within which the executable routine will function. A given routine may appear as the executable routine of several different pseudocodes. Such a feature permits the development of powerful generalized routines which are independent of a particular

Table 2. Phase Lists to the P-Q Level as Created by the C61 Context Routine

01	9-0		
	Z0	9-1	
		P21	Copy focus object
		P61	Remember name of focus object
		C31	Put name of focus in memory entry point
		P62	Remember set membership
		0	0
	C21	9-1	
		C20	Create Z7
		0	0
	Z7*	9-1	
		P191	Construct working hypothesis
		P63	Remember name of hypothesis
		C31	Put name in memory entry point
		P64	Remember how hypotheses formed
		0	0
	D4	9-1	
		D40	Determine whether subject should proceed
		0	0
02	9-0		
	Z1	9-1	
		P131	Select dimensions to vary
		P141	Select new dimension values
		P151	Create search criterion
		P64	Remember search criterion
		0	0
	Z2	9-1	
		P51	Search board for object
		P65	Remember object
		C31	Put name of object in memory entry point
		P66	Remember how object found
		0	0
	C37	9-1	
		C36	Create procedure DO
		0	0
	DO*	9-1	
		Q50	Determine whether object meets subject's needs
		0	0
03	9-1		
	Z3	9-1	
		P71	Transfer object to experimenter
		E93	Designate set membership of object
		P62	Remember object designation
		0	0
	C38	9-1	
		C39	Create procedure Z4
		0	0
	Z4*	9-1	
		P501	Recall object designation
		C41	Pop memory entry point list
		P91	Mark relevancy of dimensions
		P171	Revert dimension values
		0	0
	D1	9-1	
		Q101	Determine whether concept can be presented
		0	0
04	9-0		
	Z5	9-1	
		P121	Form a concept
		P67	Remember concept
		C31	Put name of concept in memory entry point
		P68	Remember how concept formed
		0	0
	Z8	9-1	
		P72	Transfer concept to experimenter
		E94	Designate correctness of concept presented
		P69	Remember designation of concept
		0	0
	C22	9-1	
		C23	Construct procedure Z4
		0	0
	Z6*	9-1	
		Q41	Acquire untested dimension
		P181	Add dimension to working hypothesis
		C31	Put name of hypothesis in memory entry point
		P64	Remember how hypothesis formed
		0	0
	D3	9-1	
		Q31	Determine whether problem completed
		0	0

*Routines created at execution time by the preceding context routine.

Table 3. Symbolic Representation of Routine P61

P61	9-0		Pseudocode	
	P60	0	Executable Routine	
9-0	0			
	A1	Input Attribute		
	V1	0		
		M1	Working Memory	
		F3	0	M1, N Flag
	A2	Output Attribute		
	V2	0		
		M10	Memory Entry Point	
		A20	0	Focus Object Attribute
	A3	Process Description Attribute		
	V3	0		
		A305	0	Remembering

context. The description list 9-0 of the pseudocode P61 contains attribute A1 whose value V1 is a list of the inputs to P60. The attribute A2 has on its value list V2, the names of the locations at which the outputs will be placed. The attribute A3 has the symbol A305 on its value list which describes P60 as a routine involving remembering. The descriptions held by the pseudocode can be used by higher level context routines to ascertain the characteristics of the routine. Such a system provides a rudimentary description of behavior. Whether they are contexters, strategies, procedures, or processes, all routines are represented in the computer program by means of this scheme.

The special interpreter [Baker & Martin, 1965a] extracts the inputs from the description list of the pseudocode and places them in the IPL-V Communication Cell H0, it then executes routine P60 in IPL-V. The outputs created by P60 are left in the location named on the output list of P61. Except for the memory processes, all P and Q level routines leave their outputs in working memory.

The pseudocode and interpreter system permit the development of general purpose programs which can be used in a number of different situations. For example: Processes P61, P62, P63, P64, etc. contain the same executable routine P60 and differ only in the information contained on their respective input-output lists. Thus, P61 may store the focus object in short-term memory, whereas P62 may remember the experimenter designation of an object choice. Such a scheme was designed to permit eventual development of contexter routines which will place information on the input-output lists of a pseudocode rather than having the human programmer code in the information, a step toward programs which can create programs.

Memory Structure Mechanics

Much of the design of the computer model is dependent upon the mechanics of the three-level model of memory employed. In the paragraphs below the working memory and short-term memory are examined in detail. Long-term memory was never constructed.

The working memory consists of only two cells—M1, N and M1, D—which are on a list called M1. M1, N contains the name of a particular piece of information, for example, the name of an object chosen from the external world or the name of a search criterion by which the subject is scanning for objects having certain characteristics. M1, D contains what we have called an unattached or dummy description list (DDL). The dummy description list contains a description of the symbol within the M1, N portion of the short-term memory, the idea being that subject has not attached the description to the item itself, but rather he has created a description which later routines will process and attach either to the element named in M1, N or to some other item of information. The rationale is that the dummy description list corresponds roughly to a chunk as discussed by Miller et al. [1960]. However, this chunk will not necessarily be attached to the item named in M1, N.

The working memory plays two roles within the simulation program. In the first role, it acts as an input buffer from the external world. All information from the experimenter such as the focus object or the designation of an object choice or a concept comes to the subject through the working memory. For example, in the case of the focus object, M1, N would contain a symbol representing the focus object and M1, D would contain a dummy description list which designates this object as being a member of the set. The information left in working memory is then acquired by a subsequent processing routine and can be stored or processed further within the concept-attainment processes themselves. The second role of the working memory is that of an internal communication device between various subroutines within the computer program. In the early days of the present computer program, it was felt that most of the information processed was obtained from the external world. However, protocol analysis very quickly showed that a major portion of the information processed by the subject was created internally, therefore a requirement existed for some means of temporarily storing a piece of information so that a series of processes could work upon it. Most of the low level routines within the computer program receive their information

```
L100 9-0
     X1   0
9-0  0
     A300 External environment
     V300 0
          E9       E9  9-1  Subjects internal M13  9-2   Structure of the external environment
                       Q1   representations        E10      Color   E10 9-3
                       Q2   of the external        E20      Ears        E11         Yellow   E11 9-4  0
                       Q3   environment            E30      Neck        E12         Blue     9-4 0
                       .                           E40   0  Tail        E13     0   Brown        A77
                       .                      9-2  0                9-3 0                        V77
                       .                           E10                 E11                      3624 0
                       Q72  0                      N10 + 50             N11 + 50
                   9-1 0                           E20                 E12         Dominance
                       A101                        N20 + 60 Dominance   N12 + 50
                       V101 0                      E30                 E13         Values
                            M13 0                  N30 + 10 Values      N13 + 25
                                                   E40
     A302 Strategy S2  9-1  Strategy list          N40 + 35
     V302 0            Z0
          S2  0        .
     .                 .
                       .
     .                 D3
                       0    0
     .             9-1 0
                       A18  Search criterion
                       V18  0
                            3671              3671 9-2     Search criterion
                            2033                   E11
                            0112  0                E32
                                                   E41     0
                                              9-2  0
                                                   A16     Objects found
                                                   V16     0
                                                           C10        C10 9-3 Object 10
                                                           C27            E11
                                                           C11      0     E22
                                                                          E32
                                                                          E42 0
                                                                          9-3 0    How object found
                                                                              A26
                                                                              V26  0
                                                                                   2163     2163  9-4 0    "From-to list"
                                                                                   3011 0   9-4   0
                                                                                                  A9       Dimension varied
                                                                                                  V9  0
                                                                                                      E10  Color E10 0 Color
                                                                                                  A10      from
                                                                                                  V10 0
                                                                                                      E12  Blue  E12 0 Blue
                                                                                                  A11      to
                                                                                                  V11 0
                                                                                                      E11  Yellow E11 0 Yellow
```

Fig. 3. Partial Representation of the Circular Memory Structure Created by the Computer Program Mark IV, Mod 2.

from the working memory and, having processed it, leave their outputs in working memory. In many cases a subsequent routine remembers the information in short-term memory. From a programming point of view, the working memory, acting as an internal information buffer, solves many mechanical programming problems which otherwise would become enmeshed in the idiosyncrasies of IPL-V itself. Working memory is very similar to the HO Communication Cell of the IPL-V except that it is in the program rather than the programming language.

The second major portion of the memory structure is short-term memory which contains all of the information relevant to solving a particular problem. The current structure of this memory is one that can best be described as a highly interconnected net. The short-term memory structure shown in Figure 3 is designed to grow as the information in the problem is acquired. However, the growth is constrained by a modular memory structure as shown in Figure 4. For example, in Figure 3 the symbol L100 represents the problem which is currently being solved. On the description of L100 is an attribute A302 whose value describes the problem by means of the current strategy. Describing the current strategy is an attribute A18 whose value list contains the names of the search critera used. Each search criteria has an attribute A16 whose value list contains the objects which have been found. Describing each object which has been found is a "from-to lists" containing the dimension that had been varied in order to find this particular object. The memory structure is, in reality, a tree; however, the information on one branch of the tree is not unique to that branch. For example, the from-to list on one branch describes what dimension was varied to find a particular object is also contained on another branch of the tree which describes how the search criterion was created from the focus object. The highly connected net of memory was originally conceived of as what one might call a circular memory, in that once it has grown over a period of time there is no real beginning and no real end to it because information is crosslinked and interlinked so heavily that the structure of the tree has become obscured. At the present time, because of the single problem solution involved, the tree does not get overly complex.

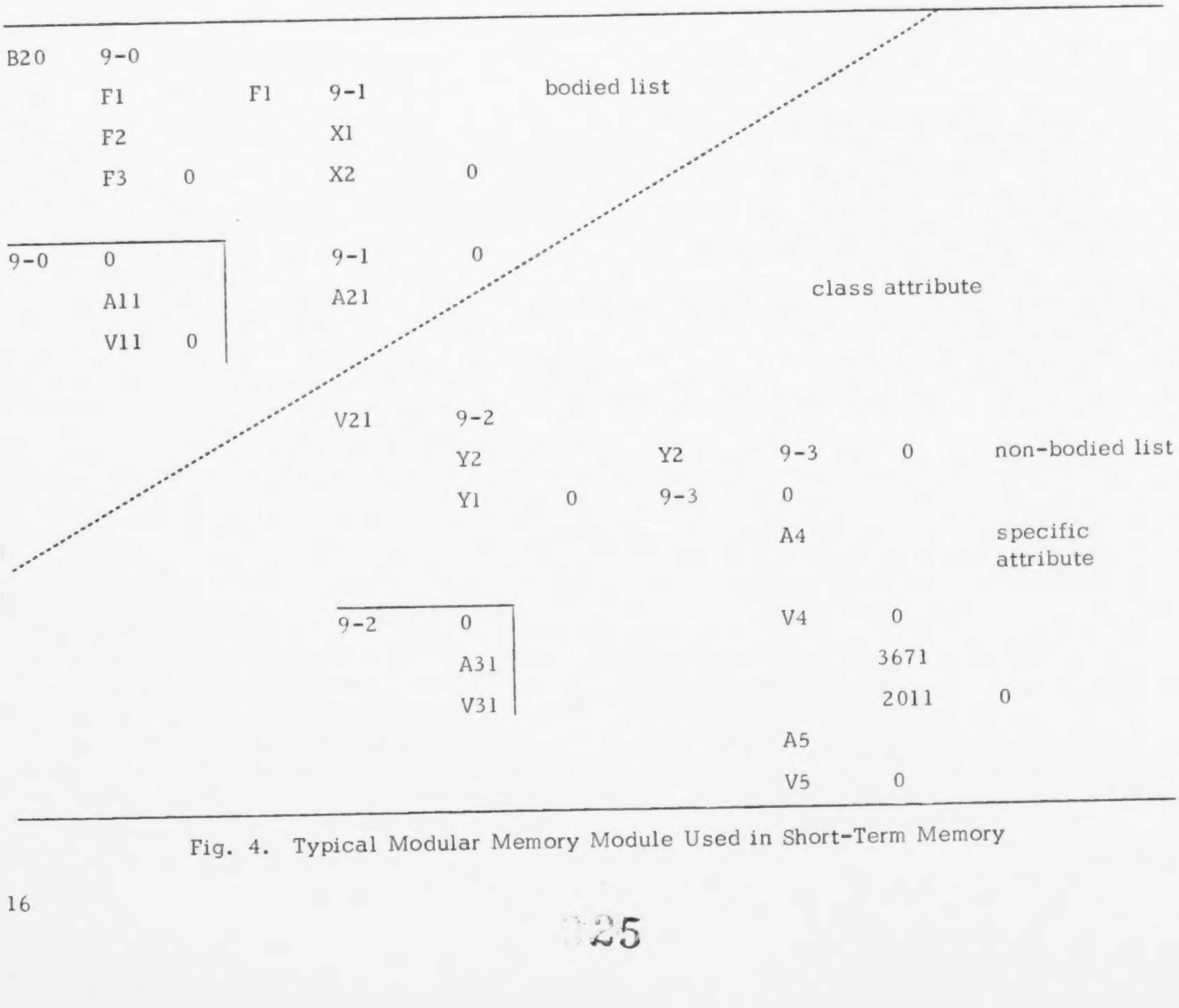

Fig. 4. Typical Modular Memory Module Used in Short-Term Memory

For clarity, the symbols in Figures 3 and 4 are IPL-V regional symbols, but in the actual program these symbols are created by the program as the information is acquired. The memory net given in Figure 3 does not exist in short-term memory prior to execution of the program. The computer program only possesses the capability to create memory as it needs to store information. Such a memory capability differs considerably from that usually employed in computer programming where the programmer accounts for every memory location used. The dynamic memory structure originating here represents a first step toward a computer program which can store and recall information without outside intervention.

Various attributes under which information is stored constitute some of the basic assumptions of the current computer program. These attributes are felt to be an intermediary step between current status and desired status, in that the investigators understand neither how to describe behavior nor how people store information in memory. Therefore, this is an approach to these particularly difficult problems. In order for the memory recall processes to work, a memory structure was developed which enabled the program to tell when it reached a point at which information was available, hence class and specific attributes were devised. In Figure 4 the attribute A21 is a class attribute as its function is to hold a series of specific descriptions on its value list V21. The symbols on the body of list V21 are dummies whose sole function is to hold a description list containing specific information. Thus, the description of list Y2 contains specific attributes A4 and A5 whose values are lists V4 and V5. Such a memory structure is symmetrical above and below the dashed line, thus permitting a single set of remember and recall routines to function at all levels. It should be noted that usable information can only be obtained from the specific attribute level, all higher levels are merely symbols representing larger units of information. The class attribute value list V21 is also time ordered with the most recent data at the top of the list. The description lists contained to the left of the brackets describe a particular list and are themselves of the same modular structure.

The long-term memory has not been designed because the between-problem variability stage of the project has not been reached. From the initial protocols and from the current computer program, it appears that what is stored in long-term memory are strategies and key pieces of information necessary to execute a particular strategy. It does not appear that a great wealth of detailed information is ever stored in long-term memory. Later development of the computer program will be devoted to studying the program of long-term memory and trying to realize an adequate model for this aspect of the memory structure.

The Memory Entry Point

One of the major problems in developing the circular memory structure was some means for entering the memory or at least keeping track of a present position in the memory having entered it. The device invented was called the "memory entry point." If one looks at the concept-attainment process, it becomes evident that as the subject goes through the various phases the information created is normally about a particular point within the process. For example, if an object is chosen from the external environment, the subject spends a fair amount of time processing various types of information about this object—what dimension was varied, what the experimenter's designation of the object was, etc. Much of the information to be stored or recalled is related to the particular item. Therefore, the object chosen serves as the memory entry point. As the process moves on to another piece of information, for example, the creation of a concept, the memory entry point changes. However, this change is normally either upward or downward on the branch of the short-term memory so that the memory entry point is really a push down, pop up list in which the subject keeps track of where he has been in memory. The problem of how to initially enter the memory structure has not been resolved, but once in the memory structure the computer program can keep a record of where it has been. The problem of initial entry was also encountered by Quillian in his memory net project; however, he chose to avoid it and entered memory at arbitrary points by manual means. Because several of the context routines have to revert to previous levels, there are two small routines, C30 and C40, which add names or take them away from the memory entry point list. The memory entry point technique is not a very satisfactory solution; however, at the present time it is a feasible one to program until a better understanding of memory processes is obtained.

Remembering of information in short-term memory and recalling of information from it are accomplished by generalized executable processes P60 and P500, respectively. The pseudocode containing P60, say P61 in Table 3, has on its input list the symbol representing working memory (M1) and a flag indicating whether M1, N or M1, D is to be remembered. The output list of the pseudocode contains the symbol representing the memory entry point (M10) and the descriptive attribute (A20) under which the information is to be stored. All storage operations are assumed to describe the symbol named in the memory entry point, and the basic process is unaffected by the type of information stored. The distinction between storage under a class attribute and storage under a specific attribute is handled within the basic P60 routine, thus the program does not need to concern itself with this distinction. The basic recall routine is P500 which is the converse of P60 and shares much of its internal programming.

The communication of the subject to the experimenter is one of the points in the concept-attainment process of little concern from a psychological point of view. Therefore, all communications to the experimenter take place through a special output register called E1 into which the subject puts information and from which the experimenter removes information in order to designate objects or concepts. It is mechanically simple, but not necessarily psychologically sophisticated.

THE DETAILS OF THE PHASE LISTS TO THE P LEVEL

Having described some of the underlying mechanics, let us turn our attention to the details of the phases created by routine C61. Some of these phases will be skipped over rather lightly, others will be described in some detail so that the reader may get the "flavor" of the program without excessive tedious detail. Table 2 above presented the lists representing behaviors to the P level which are constructed by C61. Reference to this table will aid the reader in following the discussions below.

In the initialization phase, three routines are involved, Z0, C21, and D4. Z0 remembers the focus object and its designation as a member of the set of objects defined by the concept. C21 creates routine Z7 which establishes the initial conditions within the "subject." D4 determines whether the subject is to continue onto Phase 2.

The processing of the focus of object information by Z0 is accomplished by four P level routines, P21, P61, C31, and P62. Because the subject and the experimenter both manipulate objects, it was necessary to design the program so that information received from the external environment could be separated into its external representation and the subject's internal representation of the same information. Thus, P21 creates a copy of the focus object with its dimension values in dominant dimension order and also creates a dummy description list indicating that the focus object is a member of the set defined by the unknown classification rule. If this separation is not made, descriptive information created by the subject becomes attached to the object in the external world, an undesirable situation. P21 leaves the name of the subject's representation of the focus object in M1, N and its set membership on a DDL in M1, D. The memory process, P61, remembers the focus object under an attribute of the problem list and C31 places the name of the focus object at the top of the memory entry point list. P62 then remembers the set membership of the focus object under an attribute of the focus object. At the present time routine D4 is a dummy routine as the decisions subjects make at this point have not been ascertained, but it has been inserted to keep the phase list structure consistent.

The procedure Z7 is created by the contexting routine C21; a detailed discussion of contexters is given later in the present section. In Z7 the first routine is P191, and the inputs of this routine are the name of the memory entry point and K99 which is an input constant specifying how many of the possible dimensions are to be worked with throughout this attempt at attaining the concept. The function of P191 is to create a working hypothesis from the focus object remembered by Z0. The working hypothesis is created by selecting the first K99 of the *m* dimensions on the focus object and placing them on a separate list, the rationale being that some subjects deliberately work with less than the total number of dimensions and other subjects do so inadvertently. The working hypothesis is a list in its own right; a description of how it was created from the focus object, namely the dimensions which have been removed in order to obtain the working hypothesis, is made into a dummy description list. P191 leaves the name of the working hypothesis and the name of the description in working memory M1. Following P191 is a memory process routine, P63. P63 remembers the name of the working hypothesis under an attribute of the problem list devoted to the working hypothesis. At this point, the program needs to remember the description of the working hypothesis rather than something about the problem, hence P63 is followed by a memory process, C31, which will put the name of the working hypothesis into the memory entry point list, pushing down the list and saving the name of the problem. C31 is then followed by a memory process, P64, which remembers how the working hypothesis was formed from the focus object. Thus, the problem was described by the working hypothesis and the working hypothesis was described by how it was created. The rationale underlying this type of description is that other routines and contexting operations can utilize the information to determine what has happened and then modify or create routines to change the behavior, if necessary. It should be noted that the contents of working memory remain unchanged during P63, C31, and P64 from the time P191 creates the working hypothesis and the dummy description list for describing it; however, the memory entry point changes from the focus object to the working hypothesis to make it available to the next routine or the next phase.

The second phase is the object-selection phase which consists of three routines, Z1, Z2, and C32. Routine Z1 creates a search criterion from the working hypotheses; Z2 locates an object matching the search criterion; and C32 creates the routine D0 which determines whether the subject can proceed to the next phase. The procedure Z1 consists of four routines: P131, P141, P151, and P64. The inputs to P131 consist of M10, the memory entry point, and a constant, K98, which specifies the number of dimensions to vary. In the normal conservative-focusing strategy K98 would be one; however, it can be set to any number up to the number of dimensions on the working hypotheses. Note that $K98 \leq K99$. M10 contains the name of the working hypothesis at the top of its list and it is from this hypothesis that P131 will select the dimensions to vary. Because P21 had arranged the working hypothesis in dominant dimension value order, P131 merely needs to select the first K98 of these dimensions, thus implementing the dominance feature in the program; i.e., the first dimension value on the list is the most dominant and the last is the least dominant. P131 creates a copy of the working hypothesis and puts the name of this copy into working memory on M1, N. It also creates a DDL on which it lists the names of the K98 dimensions which are to be varied at this point. The DDL is only a partially completed list which eventually will become a from-to list; i.e., it will name the dimensions, tell what their values were originally, and tell to what value they were changed. However, P131 only places the names of the dimensions to be worked with on the DDL. The output from P131 is left in M1, N and M1, D. Routine P141 takes the information from M1 and extracts the dummy description list containing the names of the dimensions to be varied. It then enters the dimension list, M13, which has been stored on the problem list L100 under the name of the external environment, ascertains a given dimension, determines what values are available other than that of the focus object, and, if there are more than two values, selects a dimension value on the basis of its dominance value. The value found is then added on the DDL under the "changed to" attribute and the value on the focus object is stored under the "changed from" value. Upon the completion of P141, the name of a copy of the working hypothesis in M1, N, and the name of the dummy description list is in M1, D. P151 is the routine which varies the dimension values to create a search criterion from the working hypothesis. It receives the working hypothesis and the DDL through M1 and will use the from-to list to change the dimension values on the copy of the working hypothesis to their new values, thus accomplishing the dimension variation. If an initial input flag dealing with awareness indicates that the subject is aware, the DDL is placed in M1, D with the name of the search criterion which has been created in M1, N. It should be noted that the working hypothesis had not been disturbed because the changing of dimension values has occurred on a copy of a working hypothesis known as the search criterion which is used to locate objects on the board. If the awareness flag indicates the subject is not aware, it is then assumed that he has inadvertently varied more than one dimension, even though he believes he is only varying a single dimension. It was very common in the protocols for subjects to choose objects which varied in more than one dimension even though they believed they were searching for an object which varied in only one dimension. Possibly this is a perception problem; however, because perception has been eliminated, awareness is handled in this somewhat mechanical fashion. If the subject is unaware, routine P151 will then delete from the dummy description list all of the dimensions and their values other than the first one. From this point on the subject's description of what he has done indicates that only one dimension has been manipulated even though multiple dimensions were actually varied. P151 is followed by a memory routine, C32, which will place the name of the search criterion on the memory entry point list with a push down of previous information. C32 is followed by a memory process routine, P64, which describes the search criterion with the DDL from the working memory.

The remainder of the simulation program operates in a fashion quite similar to what has been described above; as information is created or received from the external world, it is initially left in the working memory, and the routines which process this information create a description and leave it in the working memory. Depending upon the information and how it is used, it is either left in working memory for subsequent routines to pick up and use as information or, usually at the end of a series of routines, attached to a previous unit of information through a memory process and the memory entry point list.

As Phase 3 involves the use of an interesting contexter, the operation of this particular routine within its situation will be described in detail. At the time Phase 3 is entered, routine Z2 has located an object meeting the search criterion and has stored it in short-term memory under an "object found" attribute of the search criterion. The name of the object found has been stored in the memory entry point list, and the object has been described by the dimensions of the working hypothesis that were varied in order to find it.[1] The first routine in Phase 3 is procedure Z3 which consists of processes P71, E93, and P62. Routine P71 is a memory output process which transfers the subject's name for an object to an output buffer called E1 from which the experimenter will receive the information. Routine E93 is an experimenter routine which acquires from the E1 buffer the subject's name for the object chosen and compares the dimension values of the object with those of the concept to ascertain whether or not the object contains the dimension values of the underlying classification rule. E93 creates a dummy description list similar to those previously used which will contain a designation attribute and a value of *yes* or *no* for the set membership of the object choice. E93 also returns the subject's name for the object to M1, N so that the subject may associate the designation with the object he has presented to the experimenter. Because the memory entry point contains the name of the object found, a memory process, namely P62, can be used to attach the experimenter's designation in working memory to the object choice in short-term memory.

The experimenter's designation of the object is information from the external world, hence it is mandatory that C61 insert a contexting program at this point. Again some corners have been cut in that the appropriate contexting routine for this situation, C38, has been preprogrammed whereas in a more sophisticated program the C61 contexter would analyze the total situation and create the contexting routine C38. However, this level of sophistication in the program development has not been reached. The contexting routine C38 will create the routine Z4 which is the reaction of the subject to the experimenter's designation of the object. Initially it creates a description of the characteristics of the required Z4 routines. C38 then receives from the input list its own location in the phase list that the interpreter is currently executing. Using this information, C38 ascertains whether or not the next symbol on the phase list has a description matching that of the routine Z4 which it wishes to execute. If the routine following the C38 contexter is a Z4 routine, it will be removed from the strategy and its symbol replaced by the symbol representing the new Z4 which will be created. If no Z4 symbol follows C38, as in the first time through the phase, a symbol to hold a position for the Z4 routine is inserted on the phase list. Notice that at this point the phase list merely contains a symbol whose description indicates what the behavior should try to accomplish; however there is no executable subroutine associated with the particular symbol. The phase list is also described through the use of the DDL technique to indicate that a routine has been either inserted or replaced on the phase list. The long-term goal is for contexters to utilize this change description to ascertain what has occurred during the execution of the program. The contexter C38 uses the memory entry point to obtain the name of the object and through a descriptive attribute ascertain whether it is a *yes* object or a *no* object. If the object was designated a *no*, C38 determines whether or not the subject was aware; if the subject was aware, C38 checks to see whether the number of dimensions varied was equal to one or not. If it was greater than one, no information has been gained; the subject consciously varied more than one dimension and received a *no* so he does not know which of the two dimensions is the relevant one. In this situation, C38 will pop the memory entry point back to the working hypothesis so that Phase 2 can be executed again. If the subject was aware and only one dimension was varied, or if the subject was unaware, the program returns to the creation of Z4. Again, difficulties have been circumvented by merely inserting routines that we know are necessary to accomplish the reaction to object designation. A routine called P502 is inserted which will recall the object designation. It is followed by C41 which pops up the memory entry point from the object found to the working hypothesis. Popping the memory entry point is necessary because Z4 must have both the object designation and the working hypothesis to react to the object designation. The next routine inserted is P96 which uses the information about the working hypothesis and object designation to flag the dimension values involved as relevant or irrelevant, depending upon the designation. Following P96 is P91 which looks at all possible values of a dimension and checks whether they are marked relevant or irrelevant. If all values are marked, the dimension itself is then marked as relevant or irrelevant. However, if any dimension value is still untested, P91 will not attempt to mark the total dimension. We have found that many subjects will not consider a dimension to be relevant or irrelevant until they have checked all *n* dimension values. If the subject is unaware of the number of dimensions actually varied, no further processes are required in Z4. However, if the subject is aware, he then also normally realizes that any dimension flagged irrelevant is no longer of concern in selecting objects and a routine called P100, which removes an irrelevant dimension from the working hypothesis, is inserted after P91. The net effect of P100 is to enable the subject to choose objects in Phase 2 which vary in two, three, or four dimensions from the focus object even though he is varying only one relevant dimension; the remainder no longer enter into any of his decisions. One can obtain what looks like rather peculiar object choice sequences; however, the subject is truly varying only one dimension. If routine P100 has been inserted, it will be followed by a memory process, P64, which remembers the description of dimensions removed from the working hypothesis so that at some later point a routine can put these dimensions back in again if necessary. The final operation performed by C38 is to put a terminal symbol on routine Z4 so that it can be properly terminated by the interpreter at execution time. At this point a rather tricky operation takes place. C38 creates the next routine to be executed and places its symbol on the strategy list; when C38 terminates, the interpreter executes this routine from the strategy list.

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[1]The reader should refer to Figure 3 to trace the levels of short-term memory involved.

Phase 3 is terminated by procedure D1 which determines whether enough information is available to present a concept. D1 consists of a single decision process routine, Q101, which uses the memory entry point to obtain the name of the working hypothesis. Each dimension of the working hypothesis is checked to determine whether it has been flagged relevant or irrelevant. If all dimensions have been flagged, sufficient information is available to present a concept. Such a test is rather stringent as it requires the subject to vary all dimensions of the working hypothesis prior to forming a concept. Experienced human subjects using the conservative focusing strategy do vary all dimensions, as they know the concept must consist of the relevant dimensions. The result of D1 is an indication to the interpreter to either continue to Phase 4 or to return to Phase 2 and vary additional dimensions. Note again that a phase terminates in a decision routine.

There is actually little variation in the routine Z4 created by the contexter C38 during the first pass through the program. However, once Phase 4 has placed previously unused dimensions on the working hypothesis, the Z4 routine can vary slightly depending upon the decision net through which it passes. C38 could be made much more extensive in the future; however, the rather rudimentary contexting operation used reflects current lack of understanding of mechanisms in reaction to an object designation. The only other contexter of any consequence in the program is C22 which creates process Z6, the reaction to a concept designation. C22 operates in much the same fashion as does C38, using factors such as the number of dimensions varied, the number of untested dimensions, and whether or not the subject is aware to create Z6.

Procedure Z6 is the subject's reaction to a concept which has been designated by the experimenter as incorrect. The procedure consists of P level routines Q41, P181, and C31. The contexter routine C22 has returned the memory entry point to the focus object so that Q41 may inspect it. Q41 uses the dimension values of the focus object to ascertain which dimensions have not been varied and creates a dummy description list containing their names. The number of untested dimensions to be used is controlled by the parameter K97, which specifies how many of the available dimensions to use. P181 uses the dummy description list created by Q41 to restore K97 dimension values to the working hypothesis. It partially undoes the work done by P191 in procedure Z7. If all dimensions have been varied and the concept was incorrect, Q41 assumes a dimension has been misflagged and P181 makes a copy of the focus object for the next working hypothesis. C31 places the name of the new working hypothesis in the memory entry point. P64 remembers how the new working hypothesis was created. The strategy now returns to the beginning of Phase 2 and is reexecuted. It should be noted that the high level contexting performed by C61 is no longer needed as a complete strategy list is available for execution. C61 merely presents this strategy list to the interpreter for execution.

The paragraphs above presented the major features of the computer model. To describe the lower level programs which the computer program actually executes would require a sophisticated knowledge of IPL-V and is beyond the scope of the present report.

SUMMARY OF THE CHAPTER

The computer model of concept attainment embodied in Mark IV, Mod 2 consists of two parallel fractionizations of the behaviors involved in a learning strategy and a memory mechanism which facilitates those two aspects of the model. The parallel breakdown consists of the contexter routines and operational routines. The former represent the higher level cognitive processes associated with developing strategies, maintaining goal-directedness, and improvement of learning. The latter represent those aspects of the model which actually perform the tasks involved in attaining the concepts. Routines which perform tasks required by the information-processing language rather than behavior required to attain a concept have been hidden at a lower level within the program. One of the difficult tasks in the present project was to recognize that operational information processing had to be separated from those higher level cognitive behaviors associated with attaining the goal. The latter have been embodied in the computer model as a hierarchy of contexting routines. The high level contexters have been designed to translate the experimenter's verbal instructions into a skeleton strategy for behavior. The second level contexters create routines associated with initializing a problem and analyzing the behaviors in a completed problem, and the third level contexters create situationally dependent procedures in an attempt to adapt behavior to the situation. Although the hierarchy of contexting routines is rather rudimentary at the current time, the distinction between operational aspects of learning and the contexting aspects of learning is a crucial one not previously made.

Because information, both acquired and internally created, plays such a crucial role in the concept-attainment process, it was necessary to create a model of memory which would enable the computer program to both remember and recall this information. The memory model created consisted of three levels: a working memory, which is an internal buffer-type memory; a short-term memory in which all of the information relative to attaining a given concept has been stored; and a long-term memory in which learning strategy and certain crucial pieces of information relating to them are stored for use in solving subsequent problems of the same or similar types. In the present model, the working memory serves primarily as a holding or communication device for information which is to be passed from one behavior to another within a section of the computer model. The short-term memory has a circular structure so that any given point in the memory structure looks as if it were the beginning of an information storage tree. Several generalized memory processes have also been programmed to permit the model to remember and recall information within this circular memory structure. Although the model has not solved the problem of how a human enters memory under a given set of circumstances, it does include a memory entry point scheme for keeping track of the subject's location within memory, once memory has been entered. The majority of work on the model has been devoted to the working memory and short-term memory; the long-term memory has not been modeled. The memory model developed, although somewhat rudimentary at the current time, has been designed with considerable expansion capabilities which provide internal flexibility without sacrificing much of the capability already acquired.

The Mark IV, Mod 2 version of the concept-attainment model can reproduce a wide range of the behavior observed in the think-aloud protocols collected from human subjects. The range of behavior is accomplished with a relatively small number of computer routines, some of which, such as the memory processes, are completely general; others, such as the contexters, are very specific. Unfortunately much of the variability is controlled by the three input constants and the awareness flag; however, even this is encouraging in that so much variability can be controlled by so few parameters. The long-term goal is to eliminate such parameters and utilize only generalized routines to accomplish what Newell [1962] has called a "solution by understanding."

III

POST MARK IV, MOD 2

The completion of the Mark IV, Mod 2 version of the computer model was accompanied by a sense of frustration. The structure of the contexters was not consistent with the basic format followed in the rest of the program, hence the computer program needed a considerable amount of work. In addition, numerous ways of cleaning up the operational programs were apparent. A period of time was devoted to studying the program and sketching how adjustments could be made, but the changes were never programmed as they were not deemed worth the effort. It was felt that any major programming effort should be made only to implement a better conceptualization, not to improve the mechanics of an old one. Prior to Mark IV, Mod 2 the importance of the higher level cognitive processes within the computer model was not understood, but the development of the contexters emphasized how crucial these processes are to a computer model. The importance of these processes and their implementation in the contexters meant that further exploration was needed in areas such as how persons select behaviors from their repertoire of behaviors, how they maintain goal-directedness during a problem, and how they structure their attempts at problem solving. Classical psychology does not appear to be interested in these problems at a level which would contribute to a computer model of concept attainment. Thus, we had reached "state of the art" limitations with regard to psychology. The final frustration was that the computer programmer who had written all of the IPL-V code and made major contributions to the total project completed his degree program and departed. It would take at least 18 months to bring another programmer up to his level of sophistication with regard to the problem and its programming techniques. The net result of these frustrations was a considerable letdown in enthusiasm for the project. Our data were about exhausted; the programming capability was diminished; and the "state of the art" in psychology seemed to have been reached. After some thought it was decided that the last area seemed more worthwhile to attack. Perhaps some psychological experiments could be devised that would yield data upon which a better conceptualization of the contexters could be based. Therefore, attention was directed toward preparing some experiments involving human subjects. The initial experiment was called the planning experiment.

PLANNING EXPERIMENT

One issue raised by the development of a computer model of the concept-attainment task was that of the processes used by a subject to create plans or strategies, and the role of instructions in forming such plans. What was needed was some way of externalizing the development of a plan, and the processes involved therein, as the subject proceeded to solve the task presented him. One way of accomplishing this was thought to be to vary the instructions given to the subject, specifically with regard to the formation of plans, and to note the resulting effects on the subject's performance. It was hoped that by providing subjects with differential amounts of clues as to the formation of a plan, some light might be shed on the processes involved. It was hypothesized that the more complete the instructions concerning the formation of a plan, the better the performance of the subject.

Methodology

Subjects. The subjects were 20 female University students whose names were obtained from the Student Employment Service.

Materials. The subjects were presented with a board on which were mounted 36 photographs of cartoon animals which were basically similar but varied along four dimensions. These dimensions and their values were body color (yellow, blue, or brown), neck length (short or long), ear length (short or long), and type of tail (straight, bent, or curly). The 36 animals were randomly arranged on the board in rows of six.

Design. A completely randomized design employing four treatment levels was employed. The treatments consisted of four levels of instruction ranging from the introductory overall instructions all subjects were given to a brief outline of the conservative focusing strategy. The treatments were defined as follows:

INTRODUCTORY INSTRUCTIONS, ALL SUBJECTS

> What you will be doing in this experiment is trying to find out what animals go together to form a category that I consider correct, in other words, to find out what the rule is that describes the category of objects that I have in mind. The rule is based on some ***systematic characteristics*** of the ***animal itself.***
>
> To start off, I will point out one object that *does* belong to the category I have in mind. From then on you will attempt to discover the rule by choosing one animal at a time, and I will tell you whether it belongs to the category or not. Whenever you think you know what the correct rule is, tell me and I will tell you whether you are correct or not.
>
> It is important that you think out loud during this experiment so I have a way of knowing what you are trying to do.

TREATMENTS ADMINISTERED AFTER FIRST PROBLEM

Treatment I: No further instruction (control group).

Treatment II: "Before you begin the next problem, it might be of help to you if you take a minute to think about how you will go about solving the next problem."

Treatment III: The instructions of Treatment II plus: ". . . so that you will get the most information from each choice that you make."

Treatment IV: The instructions of Treatment III plus: "One efficient way of doing this is to vary only one characteristic of the animal at a time from the one that I first give you."

Treatments II-IV: "Let me know when you are ready to begin again."

Procedure. All subjects were run individually. The subject was seated before the board and given the introductory instructions, followed by the first problem. In brief, the experimenter designated one card that did belong to the concept and from then on the subject indicated which of the cards he wanted membership information about. Although only the data of those subjects who did not appear to be planning in the first problem (according to criteria that will be detailed below) was to be analyzed, all subjects completed the experiment. After finishing the first problem, subjects were given additional instructions depending on the group they had been assigned to (or in the case of the control group—no further instructions), and continued to solve five more problems. All subjects received the problems in the same order. See Table 4 for the list of concepts and the focus card given in each problem. A tape recording was made of all the experimental sessions, and the experimenter kept a written record of the number of choices the subject made as well as the objects chosen.

A four-item rating scale was devised to assess the extent of planning displayed in each problem solution. Each item was rated on a five-point scale with a rating of "1" reflecting the least planning and a score of "5," the most. All subjects who received an average score of moderate planning (3.0 or above) on the four items were considered as having planned on the first problem and were dropped from further analysis. See Table 5 for the rating scale for extent of planning and Table 6 for the scores obtained on the first problem. Of the 20 subjects tested, five were considered to have planned, four from the Treatment I (control) and one from Treatment II.

Those 15 subjects who received an average planning score below "moderate" for the first problem had their remaining five problems rated on the same planning scale by the experimenter. In addition, each of the 15 subjects was rated on the development of planning across all six problems by way of a four-part scale (Table 7). The ratings were made by the experimenter from typed scripts of the tape recordings of the experimental sessions.

Results

The dependent variable was the subjects' scores on the instruments dealing with extent of planning. To test for differences between experimental groups, each individual's planning score was found for each problem separately by summing his score on each of the four scales,

Table 4. Definitions of Concepts Used in Experiment

Problem	Concept	Focus Card
I	Short neck, bent tail	Blue, short neck, short ears, bent tail
II	Yellow, long neck, curly tail	Yellow, long neck, short ears, curly tail
III	Brown, short ears	Brown, long neck, short ears, bent tail
IV	Brown, short neck, straight tail	Brown, short neck, short ears, straight tail
V	Short ears	Blue, short neck, short ears, curly tail
VI	Curly tail	Brown, short neck, short ears, curly tail

Table 5. Rating Scale Used to Measure Extent of Planning

	1	2	3	4	5
1. *Extent and consistency of planning*	Little planning, low consistency		Moderate planning, moderate consistency		Much planning, high consistency
2. *Extent and consistency of "Z's"*	Few Z's used, inconsistent and/or incorrect		Moderate use of Z's, moderately consistent		Many Z's correctly used, consistent
3. *Sufficiency-loops, repetitions, and attention to irrelevant characteristics*	Highly inefficient		Moderately efficient		Highly efficient
4. *Number of object choices*	Many more than necessary (over 18)		About average (10-13)		About as few as possible (1-6)

Table 6. Average Extent of Planning Scores on Problem I Using 5-Point Scale with 3 Being "Moderate Planning"

	Number of Ss	Average Planning Score
Excluded from analysis	1	5
	2	4
	2	3
	6	2
	3	1.5
	6	1
	N = 20	

Table 7. Rating Scale to Assess Development of Planning Over Problems

1. *Development of planning over time*

1	2	3	4	5
Little improvement, slow to improve		Moderate improvement, moderate speed		Great improvement or planned from the beginning

2. *Development of use of Z's over time*

1	2	3	4	5
Little improvement, slow to improve		Moderate improvement, moderate speed		Great improvement or used Z's from the beginning

3. *Elimination of inefficiency over time*

1	2	3	4	5
Little improvement, slow to improve		Moderate improvement, moderate speed		Great improvement or efficient from the beginning

4. *Reduction in the number of object choices over time*

1	2	3	4	5
Little reduction in number, or slow		Some reduction, moderate speed		Much reduction or as few as possible from the beginning

Table 8. Comparison of the Average Summed Planning Scores by Treatment for Each Problem Separately

Treatment	1	2	3	4	5	6
II	6.5	9.0	14.5	15.0	18.5	16.5
III	6.4	11.6	13.8	15.6	14.8	17.2
IV	6	9	13.2	14.4	15.6	16.8

Table 9. Comparison of the Average Extent and Development of Planning for Each Scale Separately

	Extent				Development			
Treatment	1 Planning	2 No. of Z's Used	3 Efficiency	4 No. of Choices[a]	1 Planning	2 No. of Z's Used	3 Efficiency	4 No. of Choices
II	4	3.25	3	3.25	3.25	3.25	3.5	4
III	3.8	3.4	3.2	3.4	3.2	3.4	3.6	3.8
IV	3.2	3.2	3	3.6	3	2.6	3	4

[a] Reduction in the number of choices.

and the group mean computed from summed individual scores for each problem. Table 8 compares the average summed extent of planning score for each problem for the three groups. No data are presented for the control group since only one subject did not demonstrate planning according to our criterion. As can be seen, the major trend is one of solving the problems with progressively more planning, but there are no systematic differences between experimental treatments. Upon inspection of the data, a statistical test did not appear warranted.

It was also possible to compare the ratings of extent and development of planning across the six problems. In Table 9 the average group rating on each of the scales separately is presented for the three treatment groups (Treatment I is again omitted). Once again no consistent differences between groups in planning over the six problems were found and no statistical test conducted.

Discussion

From inspection of the data, it seemed apparent that the major effect obtained was one of learning to solve the problem more effectively with time, and that treatment differences did not play any systematic part. While a more methodologically tight study would require a larger sample size, and some check on the reliability of the ratings made, the results of this pilot study did not indicate that further effort in this direction would be profitable.

The lack of results from this experiment which was highly structured toward obtaining treatment differences caused some concern about the earlier decision to pursue this route. It appeared that commitment to a long-term series of such experiments would result in a very low ratio of information yield to man-hours invested. Some additional minor inquiries were conducted informally with results similar to those just observed. It was also realized that a long-term commitment to such experiments would require a complete professional reorientation of the principal investigator from computers to learning theory. Thus, it was concluded that the focus of the project should return to the computer model.

A LINGUISTIC APPROACH TO A COMPUTER MODEL OF CONCEPT ATTAINMENT

In one of the earlier progress reports written about this project [Baker, 1965] it was stated "It is interesting to note that the names of the subroutines almost form a verbal description of the concept attainment strategy, a possibility which offers some interesting possibilities for a string language notation." The idea was premature in our thinking and was not developed at that time, but the flow chart books contained numerous marginal notes relating to a verbal representation of the concept attainment process. The viability of this idea was further enhanced by the development of the C11 contexter routine within Mark IV, Mod 2. The function of this routine was to receive coded representations of the experimenter's verbal instructions and to translate them into a skeleton strategy or plan for attaining the concept. The nature of this subroutine and the realization that the contexter routines represented higher level cognitive processes led to the notion of taking a linguistic approach to the computer model.

Not having a concise idea of what such an approach would entail, we decided to reanalyze the protocols and the computer program from a linguistic frame of reference. The study of the protocols revealed that the subjects used a very limited vocabulary to describe their own information processing. The flow charts of Mark IV, Mod 2 also indicated a similar limited vocabulary. The presence of a limited vocabulary and an intuitive feeling that humans represent information internally as verbal symbols suggested that the scope of the problem was within reason.

The Mark IV, Mod 2 version of the computer model was coded in IPL-V and nearly each line of the program was annotated to explain what the instructions or series of instructions was trying to accomplish. Thus, a verbal description of the total program, line by line, existed. The annotations made by a programmer tend to be more concerned with the mechanics than with the conceptual basis of the program. Therefore, a narrative which would verbally describe the existing computer model was written from the program and the flow charts. The narrative is included as Appendix C. Inspection of the narrative revealed that the descriptions of the processes are mainly in first person and the sentences are imperative in form. A close look at sentences—"Remember the focus object," "Find an object on the board with a long neck"—showed that they involve a single verb accompanied by its object and various modifiers. Basically, the verb represents an operation to be executed and the rest of the sentence represents the context within which the operation is to be performed. Such a division of functions already existed in our computer model and it also seemed to be the natural one for a linguistic approach; i.e., the operational level represents a verb and the contexter program provides the objects and modifiers of the verb. Such a linguistic approach would be extremely powerful in that one need only implement a set of verbs to perform certain kinds of operations associated with the learning task. The remainder of the model would perform a syntactic analysis of verbal descriptions of the behavior desired.

An examination of this approach at the lowest level within the computer program will show how feasible it seems. For example, P131 can be described by the sentence "Select dimension of the working hypothesis." Here the verb is select, the object is a dimension which is a property of the working hypothesis. Thus, one would write a subroutine for the verb select and the contexter would provide it with the inputs of what is to be selected and where it can be found. The mechanics of Mark IV, Mod 2 would be of help here in that the memory entry print (MEP) would contain the name of the working hypothesis and the contexter could specify that it was a dimension of the working hypothesis which is to be selected. In this example the sentence would be received from a higher level routine by the low level contexter. This contexter then would find the verb, acquire the corresponding subroutine, and use the rest of the sentence to establish the entering arguments for the verb as symbols on the input list of the subroutine. Once the process had been completed, the verb routine would be executed and the output placed in working memory.

The key elements of such a scheme already exist in Mk IV Mod 2. The interpretive scheme described by Baker and Martin [1965] enables one to implement the verbs as subroutines with their inputs and outputs being situationally dependent. In addition, due to the design of the memory structure, the internal communication within the system is by and large automatic regardless of the sequencing of the subroutines. The general form of a verb under this scheme could be as follows:

```
R211    9-1         Pseudocode
        R210   0       verb
9-0      0
        A1             verb modifiers
        V1
        A2             object
        V2
        A3             object modifiers
        V3     0
```

From the above it would appear that the linguistic approach is feasible at the executable program level at least. For such a scheme to be practical from an implementation point of view, the vocabulary would have to be quite limited and the meanings of the verbs, objects, modifiers be very specific; hence, the next step was to attempt to write the narrative descriptions of the program in a restricted vocabulary, yet retain the essentials of the system. Only the operational portion of the program was rewritten in this fashion due to our greater familiarity with this aspect of the program. The condensed form of narrative is presented below.

```
P190  Create working hypothesis from copy
      of focus object

      C190  { Enter memory [(MEP)→M1,N = CFO]
            { Use CFO as WH

      P190    Retain K99 dimension value of WH

P131  Select dimension to vary

      C131  { Enter memory [(MEP)→M1,N = WH]
            { Create description
            { Hold description

      P131  { Collect DV of WH not having "rele-
            {   vancy" attribute
            { Retain K98 DV of collection
            { Make DV list the value of "from"
            {   attribute of description
            { Collect value of "dimension" at-
            {   tribute of elements of DV list
            { Make dimension list the value of
            {   "dimension" attritube of descrip-
            {   tion

P141  Find new dimension value

      C141  { Enter memory [(MEP)→M1,N = WH]
            { Obtain value of "dimension" at-
            {   tribute of WH

      P141  { (Save value
            { Choose DV
            { Is DV an element of WH ?
            {   Yes—choose again
            {   No—add "from" value to "from"
            {     list; add "to" value to "to
            {     list)
            { Repeat (   )
            { Make "from" list the value of the
            {   "from" attribute of the description
            { Make "to" list the value of the "to"
            {   attribute of the description

P151  Replace "from" DV on WH by "to" DV

      C151  { Obtain value list of "from" at-
            {   tribute of description
            { Obtain value list of "to" attribute
            {   of description
```

```
P151 (cont.)
    P151  (Save "from" DV and save "to" DV
          Replace "from" DV on WH by "to" DV)
          Repeat (   )

P50  Search board
    C50   Enter memory [(MEP)→M1,N = WH]
    P50   Search board for object matching WH
          Hold name of object
          Obtain value of "how varied" attribute of WH
          Hold value as description

Q50  Verify object chosen
    C51   Enter memory [(MEP)→M1,N = object]
          Obtain value of "to" attribute of object
          Enter memory [(MEP)→M1,N = Focus Object]
          Collect not common element of FO and object
          Hold name of collection
          Collect not common elements of previous collection and "to" list
          Hold collection
    Q50   (Is relevancy an attribute of DV,
          alt: Is DV marked?
            Yes—O.K.
            No—Set H5 negative)
          Repeat (   )

P70  Present object to experimenter
    C70   Enter memory [(MEP)→M1,N = object]
    P70   Transmit name of object to experimenter

P96  Mark DV
    C96   Obtain value of "designation" attribute of object
          Obtain value of "from" attribute of object
          Retain K96 DV of "from" list
    P96   (Save value of "from" list
          Use experimenter's designation of object to determine the "relevancy" attribute of DV)
          Repeat (   )
```

```
P91  Make conclusions on dimensions
    C91   Enter memory [(MEP)→M1,N = object]
          Obtain value of "designation" attribute of object
          Obtain value of "dimension" attribute of object
    P91   (Save dimension
          Are all but one DV marked?
            Yes—Set value of the dimension's relevancy attribute and concept name
            No—Exit)
          Repeat (   )

P101 Remove irrelevant DV from WH
    C101  Enter memory [(MEP)→M1,N = WH]
          Obtain value of "how varied" attribute of WH
          Obtain value of "dimension" attribute of description
          Obtain value of "from" attribute of description
          Create description
          Hold description
    P101  (Save DV and save dimension
          Is irrelevant the value of the relevancy attribute of the dimension?
            Alt: Is dimension marked irrelevant?
            Yes—remove DV from WH
            No—go to repeat
            Mark DV the value of the "deleted" attribute of the description)
          Repeat (   )

P171 Replace "to" value of WH by "from" value
    C171  Enter memory [(MEP)→M1,N = WH]
          Create description of hold?
          Obtain value of "to" attribute of WH
          Obtain value of "from" attribute of WH
    P171  (Replace "to" value of WH by "from" value
          Make "to" the value of the "from" attribute of description
          Make "from" the value of the "to" attribute of description)
          Repeat (   )

Q101 Can concept be presented?
    C101  Entery memory [(MEP)→M1,N = WH]
```

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Q101 (cont.)

```
       (Obtain value of "relevancy" at-
         tribute of DV
Q101    Was value obtained?)
           No—Exit, set H5 negative
           Yes—Repeat (   )
```

P121 Form concept

```
       Enter memory [(MEP)→M1,N = WH]
       Create description and concept
         name
C121   Hold description
       Make WH the value of the "how
         formed" attribute of the description

       Collect elements of WH having
P121     relevancy attribute to form
         concept
```

Q41 Find untested dimensions

```
C41    Entry memory [(MEP)→M1,N = Copy
         of Focus Object]

       Collect dimension values of CFO
         not having relevancy attribute
       Retain K97 elements of collection
       Create description
       Make collection the value of the
         "to" attribute of the description
Q41    Collect the values of the next
         upper attribute of elements of
         collection
       Make collection the value of the
         "dimension" attribute of descrip-
         tion
```

Q43 Find dimensions marked irrelevant

```
       Same as Z41 above except that
         it collects elements having
         irrelevant as the value of rele-
         vancy attribute
```

P181 Add dimension to WH

```
       Enter memory [(MEP)→M1,N = CFO]
       Obtain value of hypothesis at-
         tribute of CFO
C181   Obtain value of "to" attribute of
         description

P181   (Add element of "to" list to WH)
       Repeat (   )
```

The initial impression of this condensed narrative is that it is primarily concerned with internal data processing. A large proportion of the statements deal with the mechanics of organizing information from memory, holding the information for subsequent use, and making decisions based upon characteristics of this information. Again, this is in keeping with the earlier observation that most of the information processed is created internally during the problem solutions. Part of the problem rests with the design of the P and Q level routines which, in general, encompass too large a segment of behavior. The result is that the execution of behavior requires too many interrelated steps. The condensed narrative does provide a reasonable fractionation of these behaviors into smaller units. In many cases these smaller units are actually subroutines in the present program, although they were not structured with a linguistic approach in mind. From this condensed version, it was possible to compile a list of the verbs employed and their objects, modifiers, etc. As initially compiled, the list of verbs contained considerable redundancy and overlap of function, but after some effort the following verbs were defined:

Verb	Definition	Equivalent IPL-V Primitive
Remember	M1,N or M1,D becomes value of attribute__ of the contents of the Memory Entry Point (MEP)	J11
Recall	The value of attribute__ of the contents of the MEP is placed in working memory	J10
Enter	The contents of the memory entry point is placed in working memory	
Use	An undescribed copy of a list is created and given a name which is left in working memory	J73
Collect	(a) Elements of list X having (not having) Y as value of attribute Z are placed on a list whose name is left in working memory (b) Elements not common to lists A and B are placed on a list whose name is left in working memory (c) The values of attribute__ of the symbols on list__ are placed on a list whose name is left in working memory	
Remove	Delete symbol __ from list__	J69
Create	Make a symbol for a name or a dummy description list	J90

Verb	Definition	Equivalent IPL-V Primitive
Describe	Make Y the value of attribute Z of X	J12
Retain	Keep only the first K elements of list X	J75
Obtain	Get the value of attribute Z of list X	
Select	Randomly pick a dimension or dimension value	J16
Add	Insert symbol __ on list __	J65
Repeat	A section of the program is reexecuted	
Replace	Element __ is removed and element __ is put in its place	J67
Search	The external environment is inspected for an object matching the search criterion. Name of the object found is left in M1,N	
Transmit	Move symbol A to location B	

Property	Decision Routine	Equivalent IPL-V
Belong	Is __ an element of list __?	J62
Equal	Is symbol __ the same symbol as __?	J2
Found	Was __ obtained	
Characteristic	Is value of attribute __ of list __ equal to __?	

The utter dependence of the computer model upon the underlying structure of the language in which it has been programmed is quite clear in the list of verbs. It should be noted that the working memory is our analogue to the HO communication cell of IPL-V, but IPL-V has no analogue to the memory entry point. Nearly all verbs have corresponding IPL-V primitives which perform nearly the same function. This illustrates the fact that when programming in IPL-V one has difficulty developing higher level programs which do not reflect its characteristics. The natural question is why not write directly in IPL-V and forget Z's, P's, Q's, and the contexters. There are three major reasons why one should not do so. First, there is considerable hope of establishing a circular memory structure in which information can be stored and retrieved by the computer model rather than by the computer programmer. Second, the interpretive scheme, in conjunction with the contexters, allows the computer model to create program sequences and modify them. Third, most if not all of the messy housekeeping details of the IPL-V language are buried deep within the subroutines and are never a consideration within the computer model. If such details are not hidden, the major portion of the model becomes enmeshed with mechanics of housekeeping. Thus, what has been developed in Mark IV, Mod 2 is essentially a higher level set of IPL-V primitives which permits symbol manipulation without concern for the mechanics of memory management or housekeeping details inherent in the language. If one does not get the model above these details, it becomes impossible to develop contexters and other routines which can create program sequences which are arbitrarily ordered. Without such a higher level symbol manipulating capability, the linguistic approach would be exceedingly difficult to implement. In addition, it would seem, to this author at least, that the current approach could lead to a computer modeling language in which a verbal description is given of what is to be done and the underlying IPL-V is compiled. The existence of many verbs in subroutine form in Mark IV, Mod 2 and the Baker-Martin interpretative scheme suggest that this aspect of a linguistic approach is possible.

Although the operational verbs can be implemented, they are only a small portion of the linguistic approach. The major portion of such a model must deal not with the translation of the experimenter's verbal instructions, but with their elaboration into numerous subbehaviors. This elaboration procedure is performed covertly by the subject and is exceedingly difficult to study. To illustrate the nature of those elaborations, let us examine the following sentence in the experimenter's instructions: "You are to choose an object from the board." The sentence tells the subject what to do but does not specify how. The subject must elaborate this sentence into a complex sequence of behaviors. The sequence is roughly as follows: A basis for choosing an object must be established; a procedure for comparing this basis with the object must be developed; and certain of the resulting information must be remembered. These sentences must be elaborated even further. For example, the basis of the object choice involves combinations of dimensions and their dimension values, the number of dimensions to vary at once, and rules for deciding whether the object agrees with the criterion. All of these internally created considerations must be organized into purposeful behavior and retained for execution. The nature of this elaboration process is not entirely clear and how one would develop the mechanics for its implementation is obscure.

The General Problem Solver [Newell, Shaw, & Simon, 1958] has solved the elaboration problem within a special framework, and perhaps the approach could be adapted to the present problem. The GPS program determines the discrepancy between the present state and the desired state. It then attempts to reduce this discrepancy into smaller units, each of which are handled in the same way. Eventually resolution of a small discrepancy permits higher level discrepancies to be handled. In the present situation the experimenter's instructions could be the present state and the verb, with its requirements, be the desired state. The elaborations could consist of trying to meet the verb's requirements. Let us use the verb ***choose*** to illustrate how this might be done. A prototype of the verb ***choose*** could be stored in long-term memory and its description would contain a specification of the kinds of information necessary to execute the verb—the object of ***choose***, the basis for the choice, the environment from which the choice is to be made, and that the chosen object is to be remembered. The contexter would then use the experimenter's message to meet as many of the verb's requirements as possible. It could specify what is to be chosen and the environment it is chosen from. The rules of the programming system dictate that the object chosen be given an internal name which is left in M1, N of the working memory. Thus, the only discrepancy at this point is the basis for choosing the object. Several possibilities exist. First, one could look for the word ***basis*** in long-term memory and attempt to fulfill its requirements in a similar fashion. Second, one could invoke the conservative focusing strategy which formulates that object to be chosen by varying one dimension per object choice. The latter is easier to implement, but the former is probably the proper approach although ***basis*** would need to be properly defined as it could have several different meanings depending upon the context. If such an elaboration process were successful, the end product would be the symbol for the verb ***choose*** with its description list containing the symbols necessary to execute the verb in its present context. Thus, at the IPL-V code level ***choose*** would mean to compare symbols on one list with symbols on another list. If they match, the object is chosen; if not, a new list is obtained and the process repeated.

Another problem intrinsic to a linguistic approach is that of automating when information is to be remembered and when it is to be recalled. At the present time simulation programs remember everything or the computer programmer has built in his intelligence to define when memory processes are to be performed. The heuristics underlying automatic memory processes are completely beyond the author of the present report and perhaps beyond the state of knowledge at the present time.

Because of the difficulties associated with elaboration and self-initiating memory processes, it does not appear feasible at the present time to attempt to develop a full-blown linguistic model. A much more feasible approach would seem to be one in which the condensed narrative presented above is structured in linguistic form so that every statement involves a verb. The complete concept-attainment task could then be written out as in the condensed narrative. Low level contexters could be written which analyze these short sentences and establish the requirements of each verb. Then each verb would be executed. The higher level contexters would be used to effect the elaboration from the experimenter's instruction to the ***known*** lower level verbal statements contained in the condensed narrative. Such an approach could enable one to develop low level contexters to handle the verbs and high level contexters which would provide some insight into the elaboration process. Attacking the linguistic model from this angle would seem to offer the greatest possibility for a better understanding of the concept-attainment process. But because this is a final report for this project, others will have to implement these ideas.

IV
SUMMARY AND CONCLUSIONS

The model has been developed to its current state through a combination of protocol analysis, computer program analysis, and hours of spirited debate. A comparison of the first concept-attainment program with the current version reveals many differences—some obvious, some subtle, but, hopefully, all in the direction of increased understanding of the concept-attainment process. As was indicated in the introduction, the concept-attainment task was chosen because it appeared to be a simple task and easy to program. There was little realization that it would lead to a hierarchy of contexting routines, a model of memory, pseudocode schemes, and many other facets of the present model. Each problem encountered and the solution devised for it merely served to expose previously hidden considerations which were more difficult and more important than the problems previously encountered. Thus, the deeper the project has delved into concept attainment, the more complex the psychological processes have become. The original estimation of the simplicity of the task has changed to respectful awe at the potential complexity of even the most rudimentary cognitive behavior. Such a new frame of reference has strongly reinforced the author's conviction that computer modeling provides a powerful tool for investigating cognitive behavior.

In the preliminary report of this project [Baker 1965b] each of the various versions of the program was explained in some detail. In this chapter the important features of the several programs are summarized. The rest of the chapter has been devoted to discussing the salient aspects of what the principal investigator feels was learned from his experiences in computer modeling of the concept-attainment process.

A SUMMARY OF THE CHARACTERISTICS OF THE VARIOUS VERSIONS OF THE MODEL

During the course of development of the various concept-attainment programs, a number of major themes developed, some of which occurred rather early in the project, others only after the investigator had considerable experience in attempting to model the concept-attainment process. The original computer program, Mark I, was based upon a rather intuitive idea as to how the author would solve the concept-attainment problem. In attempting to write an IPL-V program for the concept-attainment task, it was necessary to introduce things such as random number generators to create hypotheses and record keeping systems for determining which possible combinations of dimension values had been used. The program reflected neither a clear-cut underlying strategy nor any clear-cut understanding of the underlying mechanisms. Mark I was just an attempt to see whether a program could be written to attain a concept. In addition, an attempt was made to provide the program with a certain amount of variability in its object choice behavior through the use of various constants, length of lists, and mechanisms of this general type. At the time the first program was written, such was the basic approach underlying many of the published programs for various cognitive behaviors.

A number of lessons were learned from programming Mark I version of the program and most of these were associated with programming in the IPL-V language. Although extensive subroutining is standard practice in scientific programming, it is somewhat easier to accomplish in that setting because programmers have experience with fractionating problems and recognizing reasonable subroutines. Such was not the case for the author in IPL-V as the procedures and processes involved were relatively new and how to fractionate the problem was not readily apparent. The original program tended to be one straight-line program with little subroutining. However, from the program it was obvious that greater care is needed in subroutining in simulation programs than in scientific programs and much of the later effort of the project was devoted to a continual fractionization process in order to break down the cognitive behavior into smaller modules. Although Mark I was not very sophisticated, it clearly demonstrated the feasibility of this type of programming to the present author and suggested that a longer term project would be feasible.

The learning strategies suggested by Bruner et al. [1956] have served as a focal idea within the concept-attainment project, and the concept of a strategy list appeared very early in the development of the system. Although such a strategy list was not used in the original version, the strategy list and a symbolic representation of procedures, processes, and information processing modules were developed in the flow charting books worked out during the summer of 1964. The only features of the strategy list idea that have changed very much over a period of time are some of the mechanical aspects, such as how many links follow a decision point. A number of different schemes were proposed to implement the actual execution of the strategy lists, and eventually an interpreter program was developed by Mr. Martin. The interpreter is an extremely sophisticated IPL-V program. The interpreter developed in late 1964 to execute the strategy list remained unchanged through Mark IV, Mod 0. When the high level contexting operations were introduced in Mark IV, Mod 1, it became necessary to make minor modifications in the interpreter to identify when a contexting routine had been entered.

One can observe in the descriptions of the various Marks and Mods of the program a rather subtle change in the nature of the routines at the Z and P level. In the early days the Z's and P's corresponded to rather large segments of the concept-attainment process, and it was necessary to continually redefine each of these symbols. Although the symbols Z1, Z2, Z3, etc. have been used since the earliest days, the routines these symbols represent have changed very radically. There have been essentially three major restructurings of the strategy lists and hence of the program itself. The first of these occurred at Mark III, Mod 1 [Baker, 1965c] after it was discovered that the several memory process routines were nearly identical except for the inputs. A major effort was then made to find communalities throughout the program and utilize the same processes in several different situations. The second major restructuring of the program occurred with Mark IV, Mod 0 when the circular memory structure was introduced. All of the memory processing routines, and a number of other routines, were redesigned to take into account the incorporation of the circular memory structure and the memory entry point in the program. The third major restructuring of the program occurred in Mark IV,Mod 2 where the contexting routines were introduced at three levels. The first level contexting routines, C10 and C61, created the strategy. Both the second level contexter, C22, and the third level contexters, C37 and C38, created Z level routines which were situationally dependent.

The fractionization process is by no means complete. It can be seen quite readily in Mark IV, Mod 2 that the working-memory processes need to be restructured again and some subroutines developed which will handle the transfer of information to and from working memory. Such routines have been designed but have not been programmed. The P's and Q's in the current version are still too large, and the amount of information processing they do is too extensive. A further fractionization of these routines depends upon more information about human cognitive behavior than is currently either available in the psychological literature or observable in the protocols.

One of the basic tenets of the program development was that of the "backwards" approach, starting from a program for a very experienced subject and working backwards to a subject who is less experienced in solving concept-attainment problems. Through Mark III, Mod 1 the computer model was strictly that of an experienced subject. In Mark III, Mod 2 it was discovered that with relatively little effort it was possible to create nearly all the basic types of variability required by the several types of Bruner strategies and observed within the protocols by assembling the various P's and Q's into new types of Z's. Variations within the conservative-focusing strategy have been introduced principally through the means of the constants K96, K97, and K98, although in the Mark III, Mod 2 version they were handled somewhat clumsily. In the Mark IV, Mod 2 version the three constants will elicit all of the variability, other than the wholist strategy, previously observed in Mark III, Mod 2. In Mark IV, Mod 1, the awareness factor was also introduced, which was related to the psychological dependence of the dimensions in Bruner-type materials. A considerable amount of variability can be constructed through the use of the awareness factor. Its psychological origins are considerably deeper, but the parameter is a reminder to look at this type of behavior. At the current time, the within-problem variability exhibited by the computer program is quite satisfactory, but it is unfortunate that such variability results from the "screwdriver" parameters—K96, K97, K98, and the awareness factor. The ultimate goal is to have the within-problem variability result from the "subject's" own mechanisms. Eventually, the within-problem variability will occur at the contexting level where, through ~~misanalysis or~~ other mechanisms, the program will create its own variability. Such a capability is presently provided by having those of us on the outside of the program code it in through the screwdriver parameters. Internal creation of variability in behavior is not a trivial problem and has been investigated by many other people. To solve it would mean accomplishing Newell's [1962] "solution by understanding"; this does not appear to be on the immediate horizon.

In retrospect, it appears that the major portion of our programming effort was devoted to memory structure. It was realized in the summer of 1964 that much of the success of the concept-attainment model would depend upon how adequately memory structures were modeled. In the original version of the program no attempt was made to model memory. Information was merely stored in IPL-V lists and data terms, and the computer programs were written to extract information from storage when necessary. The first version of the program in which any serious attempt was made at building a memory model was Mark III, Mod 0 in which the three-level breakdown of working memory, short-term memory and long-term memory was utilized. The two cell idea of the name and description within working memory was also invented. The mechanics were quite rudimentary and the idea of a dummy description list, although mentioned, was not fully developed. The Mark III version of the program also introduced the modular memory structure. The problem arose of determining when the program had reached a level at which information was available, and the nonbodied lists containing specific attributes were invoked in order to terminate the searching procedures. The Mark III version had a confused scheme for extracting information; some P's would use a memory process to acquire information whereas other P's would directly use the name of a list and obtain the information. The confusion reflects our uncertainty about the structure of memory.

In the Mark III version of the program, it became quite clear that most of the information dealt with by the program was descriptions of other information. The modular memory structure was designed to implement storage of descriptions rather than storage of specific items on lists. Although a rather highly interlinked memory net was inadvertently developed, it was not until a series of discussions were held with Dr. Ross Quillian at Systems Development Corporation that the possibility of completely interlinking the memory net was realized. With this concept in mind, the memory structure of the program was completely redesigned in the Mark IV, Mod 0 version where the circular memory structure and the memory entry point were introduced. Although the circular memory structure was new, the modular structure utilized in Mark III was retained as the mechanisms were well understood and seemed to be functioning fairly well. The problem of how the computer program could store and recall information under its own control is still unsolved and is one of the major unsolved problems of modeling cognitive behavior.

The subject's control of his own behavior, i.e., contexters, had its origins in the very early days of the project, all of the flow charting books carry marginal notes which record various ideas about contexting. The original contexters were conceived of as low-level programs which would establish the input list under A1 and output list under A2 for each of the P routines, but the low-level contexters were never programmed due to structural difficulties in Mark III. After development of the circular memory structure in Mark IV, Mod 0, it became obvious that representation of the total concept-attainment process was necessary, and a rudimentary model of the total contexting process from the experimenter's instructions to the actual execution of the program was made. Again the low-level contexters escaped our attention, and computer programs to set up the inputs to the various P's have not been written in that an adequate description of behavior is not available. The attribute system used in the experimenter messages to describe gross behavior and also to describe the procedures on the strategy list is a temporary device to be used until a better insight is gained. Newell's article [1962] on the internal organization of computer programs provides several examples of his attempts to resolve this problem within the General Problem Solving program. A system for describing behavior which a computer model can handle alone is an extremely difficult task and so far has eluded investigators involved in computer modeling of cognitive behavior. The final outcome from the study of the contexter was the idea for a linguistic model of the concept-attainment process. It appears to be reasonable to employ the mechanics of Mark IV, Mod 2 in conjunction with a rudimentary syntactical analysis capability to construct a

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contexter hierarchy which deals solely with an English language representation of behavior.

MODELING CONSIDERATIONS

Internal vs. External Information

In the early days of the project, the concept-attainment process was thought to be primarily one of processing information received from the external world. However, after the computer program had been developed to the current point, it became apparent that the majority of the information processed does not come from the external world but is created internally by the subject. Thus, although concept attainment is an information-processing problem, the amount of external information processed minimal and consists only of the objects, the experimenter's instructions, and his designation of object choices or of concepts. It should be noted that perception problems associated with observing dimensions and their values were intentionally omitted, but this is typical of most existing computer models. As the majority of information is created internally, it is the task of psychologists to determine what internal information is created and how it is processed. For example, from a protocol it is quite easy to determine that when an object is designated as a *yes* or a *no* the subject creates information about the relevancy or irrelevancy of a particular dimension or dimension value, but on what basis he does is not clear. If one is to develop an adequate computer model, one must know what information is created, on what basis a subject created the information, what he did with it, and how much of it was retained for longer term use. Without substantial knowledge of this type it becomes difficult to develop sophisticated computer models. Unfortunately the current techniques of psychological experimentation do not seem capable of providing the requisite insight.

The Memory Model

Analysis of the concept-attainment task indicated that any significant modeling of the concept-attainment process was impossible without some model of the structure of memory and of the cognitive processes associated with remembering and recalling. The three-level structural model of memory developed for the present simulation program appears to be a reasonable model. The idea of the working memory functioning as a temporary holding-type memory has proved to be an exceptionally useful concept as it enables information to be communicated from routine to routine without going through the rather complex mechanisms associated with short-term memory.

Conversations with Dr. Ross Quillian elicited the observation that the memory structures in the earlier editions of the concept-attainment program were very nearly memory nets. Later, the memory structure was redesigned to the present circular memory structure. The use of a list structure format for memory has seemed excessively artificial to the present author and the circular memory structure appears to provide a reasonable alternative. The significant feature of the circular memory structure is that, although the memory processes in the model can store and recall information, the memory does *not* consist of a series of predefined bins into which information is automatically placed. The memory structure is dynamic in that storage is created in the proper structure as the information is created, rather than knowing ahead of time that certain pieces of information are to be stored in given registers. The dynamic nature of the circular memory structure also gave rise to the problems of entering the memory structure and keeping track of where one is in memory. Because the order in which memory is created is situationally dependent, the memory entry point (MEP) has proven to be quite successful in performing the bookkeeping associated with the circular memory structure. The problem which is as yet unresolved is a mechanism for entering an existing memory structure, such as would be required when a second or subsequent concept-attainment problem was begun.

The memory model employed is somewhat clumsy mechanically; however, its structure does provide for the eventual inclusion of both interference and decay-type forgetting. The inclusion of forgetting in the computer model would again raise many more problems than it would solve but should prove to be of interest.

Attribute Structure

The Mark IV, Mod 2 computer model involves approximately 25 attributes under which various types of information can be stored. These attributes were divided into class attributes and specific attributes, and certain mechanics were invented in order for the computer program to ascertain what information was available under these attributes. For example, under a class attribute chunks of information are available; under a specific attribute, unique items of information exist which can be extracted. The attributes employed were a function of the particular experimental situation modeled and represent an initial approach to the exceedingly difficult task of describing behavior. The next logical step appears to involve creating both class and specific attributes from a minimal set of basic descriptive attributes, but the logical basis for defining such a basic set of attributes is not presently obvious to the author. Given such a basic situation, it does appear to be quite possible for the computer program to create both class and specific attributes when required by the situation. Thus, the computer model could handle the descriptive processes using its own capabilities. The attributes currently used were devised by the computer programmer and as such merely identify or label different units of information which he believed necessary. However, to shift this responsibility from the programmer to the computer program is a major step which clearly needs to be taken.

Use of Protocols

The think-aloud protocols, especially those with experimenter interrogation of the subject, have been an excellent device for eliciting the grosser behaviors exhibited by subjects within a concept-attainment task. The think-aloud protocols have been extremely disappointing in providing answers to the more fundamental questions which now need to be answered. It seems that the "state of the art" limitation in protocol analysis was reached, and it is difficult to elicit much more information from the protocols than has been extracted. The failure of the protocols to provide answers to questions about the internal mechanisms of human subjects, such as contexting and memory, suggests that new techniques of psychological inquiry are desperately needed in order to study covert behavior.

Contexters

During the early phases of the present modeling project, the computer model consisted essentially of the strategy list with its Z routines, P routines, and Q routines. Upon more detailed fractionization of the computer program itself, it became increasingly apparent that the central executive function had to be separated from the operational function. There are actually two parallel processes which occur as a human being solves a problem. One was designated the contexting process which is the monitoring, supervising, goal-directing aspects of human behavior, i.e., the higher level, cognitive processes. The second is the operational aspects involving what one might call the subject's abilities, habits, or mechanisms. Once the difference between the contexting program and the operational program was conceptualized, a major restructuring of the computer program was possible and made for significant differences in the model of cognitive behavior.

A contexter can be viewed as creating a plan or strategy for behavior. At high levels in the model it creates plans for overall behavior and at low levels it creates plans for very specific actions. Such planning hierarchy was first envisioned by Miller, Galanter, and Pribram [1960] when they suggested the existence of plans which create plans. Their scheme and the present hierarchy of contexters have two implications for the internal organization of a computer model. First, the program must be organized so that it can treat itself as data; second, a contexter must be able to create programs from the "abilities," i.e. subroutines, possessed by the "subject." In the first case, the contexter routines must be able to analyze, modify, and otherwise manipulate the computer program itself. Without such abilities, the contexters cannot improve the subject's performance as a function of experience. The mechanics of treating the total program, including the contexters, as data can be accomplished through interpreter schemes such as that programmed by Baker and Martin [1965] in which the strategy or plan is a list of symbols representing behaviors. However, the symbols are executed by means of an interpreter rather than directly in the underlying language. Because these symbols are placed on lists, they can be treated, through the list processing language, as if they were data and can be manipulated by the contexter routines. Such a requirement rules out compiler-type list processing languages which are not capable of modifying the source language at execution time of the object program. Thus, it would appear that more sophisticated interpreter-type languages such as IPL-V will need to be developed. It should be pointed out that the Baker-Martin scheme divorces the contexting operations from the interpreter as the contexters are also executed by the interpreter.

The lack of differentiation between data and program means that both must share a common internal representation and that the internal organization of the computer program must facilitate both the storage and retrieval of information in some uniform fashion. In most existing computer models, the memory processes have been avoided by having the computer programmer remember where he stored the information and recall it for the program via the code he writes. Under an adequate computer model, the program should decide what should be stored and store it so that the program can retrieve it through its own recall mechanisms when the information is required. Uniformity of storage and retrieval in the present model has been implemented through the use of a modular memory structure accompanied by basic remembering and recalling routines which are a function of the structure of the memory rather than the list processing language employed. However, the programmer still decides what to remember and when to recall the information.

In addition to devising a system through which the program can be manipulated, it is necessary to provide contexters with the capability of creating new programs based upon new generalizations inductively acquired; i.e., the contexters should be programs which can create programs. Because the lowest level of detail in a computer model consists of basic processes which can be executed, i.e., the "abilities" possessed by the subject, all other levels of a computer model can be composed of the symbols which represent these basic processes. Hence, the procedure for creating new processes, plans, and contexters consists of restructuring these basic processes in an appropriate order. However, if the context routines are to have the capability of creating plans, they must "know" or be able to ascertain the capabilities of the basic processes and of the higher level routines which derive from them. There is a crucial and as yet unresolved requirement for being able to describe the characteristics and capabilities of a behavior regardless of the level at which it appears in the computer model. One rudimentary way is to consider a process as a transformation and use its inputs and outputs to describe the nature of the transformation. However, Newell [1962] indicates that this is not an adequate description. It would appear that the most feasible method would be to design computer models which manipulate verbal material as in the linguistic approach described in Chapter III. Regardless of how the description problem is solved, it is quite clear that unless it is solved, progress in computer models will be very slow. It would appear that Newell's "solution by understanding" requires a prior "solution by description."

Programming Techniques

A number of computer programming techniques were developed by the project staff. The foremost of these techniques was the pseudocode interpreter system which enables representation and execution of the model as a list of symbols. The pseudocode scheme also provides the mechanical basis for the capability of the contexters to create programs from existing programs; a major unsolved task is the conceptual basis for such a capability.

The circular memory structure and its generalized remembering and recalling routines hopefully provide the basis for future computer programs which can perform these processes without human supervision. Again the mechanics have been provided but the requisite knowledge upon which to base the processes is not available.

The development of computer programs in which the program can be treated as data and new behavior sequences can be created requires that the computer model be independent of the mechanics of the language in which it is coded. In any programming language there are a large number of necessary housekeeping tasks which are unrelated to a computer model of cognitive behavior. For example, in IPL-V one must erase unneeded lists, push and pop the HO communication cell, and make copies of lists. If the computer program is to truly be a model, it should not be cluttered by additional features which take account of the housekeeping details associated with the underlying programming language. Freedom from such mechanical details can be accomplished through the use of an interpretive system, such as the pseudocode in the Baker-Martin [1965a] scheme. Alternately, if a "solution by description" were achieved, it could serve as the basis for the development of a compiler-level modeling language. One could then model the cognitive behavior in this language and be freed from the underlying list processing or other such language. Regardless of the method, the computer model needs to be freed from the housekeeping mechanics of the underlying programming language.

RESEARCH IDEAS GENERATED BY THE COMPUTER MODEL

1. In that the total computer model was developed around the idea of a strategy or plan, there exists a need for more information on what processes a subject uses to create plans and on the role of instruction in forming such plans. As was observed above, the present computer program assumes that the experimenter's instructions have a crucial role in the establishment of at least a gross plan of behavior. Unfortunately the planning experiment did not indicate that various levels of completeness of experimenter's instructions had any effect. Nonetheless the basic validity, or lack of validity, of the Miller, Galanter, and Pribram [1960] plans has not been demonstrated.

2. When one considers the vast realm of behavior which human beings are capable of exhibiting, it is remarkable that in a given situation they normally produce behavior relevant to the problem at hand. It may not be effective in a given situation, but usually it has some possibility of being useful. One of the outstanding features of the protocols was that almost all of the subjects very quickly produced a plan for solving concept-attainment problems. If subjects had not been able to select behaviors rapidly and appropriately, it would have taken a much greater period of time for them to solve these types of problems. Therefore, an important area of research is how humans select a specific behavior from their repertoire of possible behaviors.

3. In that the communication between the experimenter and the subject is minimal in the concept-attainment experiments, it is unusual that subjects can maintain a sense of goal-directedness during the entire experiment in the absence of many external clues. The relationship between what the subject sees as the task to be accomplished and the kinds of information he utilizes to ascertain whether he is making progress toward that goal needs to be investigated quite carefully. Analysis of the protocols showed that most subjects had some understanding of whether or not they were going in the correct direction despite the lack of external clues. It would be very interesting to ascertain what types of internal information they were utilizing to maintain this goal-directedness.

4. The memory entry point which was created to maintain some sense of order in the circular memory structure raises many questions about how people store information and, more importantly, how they get it back once it has been stored. The nature or structure of information stored in the human brain is not intuitively obvious. Subjects are adept at getting the information at the proper time without any great amount of visible effort. Logical analysis of the concept-attainment problem suggested that people followed some type of memory entry point sequence in that they tend to remember information about what they are currently working with without much concern for the details of the previous operation. However, many alternative models are equally reasonable.

5. Much effort was devoted to trying to introduce within-problem variability into the computer model. It was severely hampered by a lack of understanding as to how people make errors. Stimulus-response psychology has traditionally blamed errors upon the stimulus materials; however, our model tends to indicate that these errors are more likely due to errors in the contexting operations and errors in internal description rather than in the stimulus materials themselves. It would be most helpful for someone to conduct experiments which try to obtain some understanding of how humans make errors in the internal processing of data.

6. One of the large what one might call fudge factors in the current program was the awareness flag developed after the protocols showed that many subjects inadvertently worked with less than the full set of dimensions. In some cases it was clearly a perceptual problem; in other cases, it was possibly an oversight. If a subject was asked to name the dimensions, he would mention all five, yet in working on a given problem, he might deal with fewer. The behavior raises a question of how people decide upon using less than the full information. There are two sides to this coin, one of which is when the subjects know they are using less than the full amount of information and the other is when they do not. The interesting facet in the latter case is why don't they know?

7. Analysis of the protocols indicated very clearly that people do not remember the sequence of object choices; rather they remember strategies and reconstruct rather than recall the sequences. Such an observation raises many questions about the concepts currently in vogue about memory and what is stored. The protocols led to the distinct impression that people remember extremely little detailed information but do remember with great fidelity the strategies, procedures, and processes necessary to reconstruct the sequence of events. It appears that people keep detail around just long enough for it to be of

some use. However, any information stored for a longer period of time is usually stored in the form of a procedure, i.e., a strategy accompanied by enough basic information to repeat the process itself. Such a conceptualization of memory enhances the idea of the working memory and short-term memory, where working memory keeps the details just long enough for them to be used and short-term memory keeps enough of the salient information so that the process can be repeated. It would appear that the long-term memory is devoid of a great amount of detail but contains strategy lists and the necessary and sufficient amounts of crucial information to execute the strategy. However, the mechanisms by which people reconstruct rather than recall are not obvious and seem to be a good topic for future research.

8. During the development of the short-term memory, it was observed that the information was stored in a highly interlinked fashion, no matter what structure of memory was used. The existence of such extensive interlinkage seemed to suggest that interference in memory could be caused by access to inappropriate information resulting from the excessive linkages of the stored data. It would be very interesting to perform some experiments in which one deliberately caused subjects to remember certain types of linkages and then try to observe the amount and nature of interference that occurs due to the preconstructed linkages.

The types of information that are required for further development of the present computer model along the lines indicated suggest a rather different realm of psychological research than is usually reported in the literature. The concern is with what the subject does rather than what the experimenter does. In most current psychological literature, the experimenter is actually varying the material, etc., and little other than relatively gross outputs is ever attributed to the subject. The protocol analyses have shown that these gross outputs are not really informative about the processes, procedures, and so on utilized by the subject. In essence what is needed is some research in depth as to what subjects *do* in experimental situations rather than what they *produce*.

THE STATE OF OUR ART

The listing of Mark IV, Mod 2 is provided as Appendix C and includes a symbol cross reference. The program was included to enable those familiar with IPL-V to match what was said about the program with what the program actually does. Adequate documentations of large, complex computer models is a difficult task and many discrepancies will probably be noted.

One of the unfortunate realities of computer modeling research is that it is a very lonely endeavor. The total number of such researchers is very small, their distribution sparse, and their interests very specialized. It was difficult to conduct a meaningful dialogue even with others interested in simulation of concept attainment, as each researcher has his own frame of reference and, once beyond generalities, such a dialogue requires intimate knowledge of the details of the models discussed. Inadequate documentation of published computer models is partially at fault here, but in many cases adequately documented programs are complex and deviously interdependent so that what is said and what happens is discrepant. During the course of the present project Professors L. Uhr, L. W. Gregg, R. C. Calfee, R. L. Venezky, and the author held a series of informal faculty seminars in which it was possible to reach the level of detail necessary for meaningful discussion of various computer models. These seminars were extremely fruitful and are needed on a much broader scale if the field is to progress.

Looking back to the beginning of the project, it can be seen that considerable progress has been made. With each new version of the computer program, the problems attacked were more sophisticated and the unsolved problems exposed more irretractable. What was once conceived of as a simple problem in computer application has become an extremely complex problem requiring answers to questions which are far beyond existing knowledge. At present a complete restructuring of the conceptual basis of the program from plans and strategies to language processing appears to be required. The linguistic approach coupled with many of the techniques derived within the present project would initiate a new approach to the modeling of human behavior. Such an approach might prove to be the stepping stone to the desperately needed new techniques for studying covert human behavior.

The concept-attainment program currently available, namely Mark IV, Mod 2, is a very rudimentary model of the concept-attainment process and of itself does not exhibit a great deal of what a specialist in simulation would call "interesting behavior." However, the author has not been overly concerned about this aspect as the computer program essentially represents a repository for ideas about the concept-attainment process acquired to date. From this point of view, the program can be considered quite successful in that a reasonable understanding of at least the grosser mechanics of the concept-attainment process was obtained. In the modeling of the concept-attainment process, many problems have not been solved, but the modeling process has provided a good idea of what problems need to be solved in order for further progress to be made.

The sequence of events occurring within the present research project has followed a pattern typical of most computer modeling research, namely rapid early progress which suddenly reaches an asymptote of no progress. That this pattern exists was forcefully presented by H. L. Dreyfus [1965] in the RAND report entitled "Alchemy and Artificial Intelligence" where he drew the analogy between the alchemist's early success in extracting quicksilver from what appeared to be dirt, which resulted in a fruitless attempt to turn lead into gold, and the early success in the simulation field. An early success-long term failure pattern has been observed in nearly all aspects of computer modeling—problem solving, learning, chess playing, theorem proving and so forth. Dreyfus felt that simulation of cognitive processes reached their developmental asymptote very quickly and that future progress was limited by the inability of present computers and computer models to handle what he called "fringe consciousness." By this term he means the wide array of subtle information which a human unconsciously draws upon when performing any cognitive task. Fringe consciousness would include information such as problems done in the past, psychological qualities of the experimenter's voice, remote prior experience in other areas which can be transferred to the present problem, and so forth. Dreyfus states that the range of such information is so great that, even if it could be enumerated, digital computers could not search it in reasonable time. The present computer model encountered the fringe consciousness problem and many of the "fudge" factors were simply attempts to avoid the problem. It appears that the fringe consciousness problem is unsurmountable if attacked head on. The only reasonable solution would seem to be to develop some creative high level theoretical abstractions that enable one to circumvent the necessity of including a human's complete range of experience within a computer model.

On the basis of the author's experience with the present research and what Dreyfus has described as the typical pattern in most modeling of cognitive behavior, it is evident that future progress is going to be slow and require the expenditure of considerable intellectual effort.

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APPENDIX A
THINK-ALOUD PROTOCOL

Problem I (Concept is short neck, bent tail)

E: This card belongs to the concept. (Focus card is blue, s. neck, s. ears, b. tail)
S: Ah, lets see it is blue and has a short neck, and has a straight tail. Ah
E: This card.
S: This?
E: Yea
S: Short neck, straight tail
E: No that tail is bent.
S: Oh wait!
E: See this has a straight tail. You can compare them.
S: Oh, that's bent and that's straight. Alright, I was looking at this, so I thought that this was the real bent one.
E: Oh, I'm sorry.
S: In other words these are the same categories.
E: Well I call them curly.
S: So there is another category.
E: There are three kinds of tails yea.
S: Let me see.
E: Straight, bent, and curly.
S: O.K., Ah
E: Or you can call them what ever you want to.
S: It has a bent tail, it's blue, short neck, short ears. Um. Let me see, uh
E: What are you looking for?
S: I'm looking for the same thing in another color to see if color is one of the categories, one of the characteristics. Is this the one? It's brown, has short neck, and bent tail. (brown, s. neck, s. ears, b. tail, varying only color)
E: Yes, that does belong.
S: So then it doesn't matter what color it is. Um, I'll find one in yellows to see if . . . I can see this one in yellow. Does that belong (yellow, s. neck, s. ears, b. tail, varying only color again)
E: Yes that belongs.
S: Well, three of them are the same exactly except they're in different colors, therefore, the one I'm looking for . . . it doesn't matter what color the one I'm looking for is. So the characteristics are, let me see, um . . . I'm going to find out if the tail has to be bent or not, so I'll take one that has a straight tail and no ears.
E: What are you looking for?
S: I'm looking for, oh, here's one with a straight tail, and big ears. Oh wait, a straight tail and small ears. Does that fit in? (brown, s. neck, s. ears, str. tail, varying color and tail)
E: No, that does not belong.
S: So obviously the tail is the one, the characteristic that uh, rules that one out. Does this belong? It has a long neck and a curly tail. (brown, l. neck, s. ears, curly tail, varying color, neck, and tail. But *S* should have learned that tail is relevant)
E: No that does not belong. So now what are you thinking?
S: I'm thinking that, well, something with a curly tail does not belong in the category. Is it possible that the card I'm looking for must have any color, must have a bent tail, and no neck, and short ears, or short neck and short ears.
E: Are you guessing at it now?
S: Well Uh-hum actually I am.
E: Would you mind repeating it.
S: Bent tail, short neck, no ears, uh, short ears, and it doesn't matter what color it is.
E: No it is not correct.
S: Well I will try and rule out some other category. Does uh, Does this belong? Has all the characteristics that the first part had, but it has big ears. Does this belong? (blue, s. neck, l. ears, b. tail, varying just ears)
E: Yes it does belong.
S: Oh, so big ears are part of the category. Uh. Does this belong? (blue, s. neck, l. ears, curly tail, varying ears and tail. *S* doesn't seem too sure of tail)

E: Why are you asking?

S: Because it has big ears, and a curly tail.

E: No that does not belong.

S: Then the curly tail must be a characteristic that doesn't belong. Does this belong? Has a straight tail and big ears. (blue, l. neck, l. ears, str. tail, varying neck, ears, and tail)

E: No that does not belong.

S: Then a straight tail does not belong. Well, then after searching out all the characteristics, I feel that the card I'm looking for must have any color, but it must have a bent tail, and a short neck, but it can have any kind of ears.

E: That is correct. Uh-hum, O.K.

Problem 2 (Concept is yellow, long neck, curly tail)

E: This card belongs to the concept. (Focus card is yellow, l. neck, s. ears, c. tail)

S: Yes, it has a long neck, and it's yellow, and it has a curled tail, but has no ears. Now I'm going to test for, color I think first. Uh. Here is the same thing in blue, long neck and curled tail, and small ears. Does that fit? (blue, l. neck, s. ears, c. tail, varying just color)

E: No that does not belong.

S: So obviously it has the same characteristics, but a different color, then the color rules it out. Does this belong? Oh, wait now I'm sorry.

E: What are you looking for?

S: A brown animal with long neck, small ears, and a curled tail. But I don't seem to find one. Here's one. Does that fit into the category? (brown, l. neck, s. ears, c. tail, varying color again. In all these problems, *S* always varied color first and checked it twice.)

E: No this does not.

S: Well I tested for the two other colors shown on the chart therefore, I feel that color is a characteristic that rules an animal out, so the color of an animal must be yellow. Now I will check for the size of the neck. Uh. Here is the same card, but only that it has a small neck, same animal. Does that fit in? (yellow, s. neck, s. ears, c. tail, varying only neck)

E: No that does not belong.

S: Well then the size of the neck is another characteristic that I'm looking for. It must have a long neck. Uh. The same card with a long neck, and big ears. Wait now I'm sorry. Here, does that card belong? (yellow, l. neck, l. ears, c. tail, varying only ears)

E: Yes, it does belong.

S: So it doesn't matter what size the ears are? Here is an animal. I'm looking for an animal with a short neck to see if it is the size of the neck. (But *S* just checked the neck) Oh here, well it has a curled tail. Oh does this animal fit in it has a bent tail? (yellow, s. neck, s. ears, bent tail, varying neck and tail. *S* is either not paying attention or he has a very short memory.)

E: No this does not belong.

S: Does the

E: What did that tell you?

S: Well it told me that, oh wait, I haven't tested really for a bent neck. Does this card with the short neck and curled tail fit in? Yes it does. (yellow, s. neck, s. ears, c. tail, varying neck. Same as 3rd choice. It seems that *S* forgot the designation rather than forgot he chose it.)

E: No it doesn't.

S: Oh, it doesn't!

E: Did you forget this?

S: Yes I forgot that. So the size of the neck does matter. Uh. I'm looking for, oh here's one. An animal with no ears, a long neck, and a bent tail. Does that belong? (yellow, l. neck, s. ears, b. tail, varying just tail)

E: No it doesn't belong.

S: Well that tells me that the bent tail is out. Now I'm looking for an animal who has a long neck, and a curled tail, and no ears. It there one? Oh, it's the only one there. I think that I have found it. The animal must be yellow, must have the curled tail, must have a long neck, and must have no ears, or small ears.

E: Short ears?

S: Short ears.

E: No that's not correct.

S: Oh wait, I think that I tested for the ears. Then it must have all the characteristics, but it doesn't matter what ears.

E: O.K. (Laughed) That's better.

Problem 3 (Concept is brown, short ears)

E: This card belongs to the concept. (Focus card is brown, l. neck, s. ears, b. tail)

S: It is a brown animal, it has a long neck, it has short ears, and a bent tail. Uh, I would like to test for color first, so I will find the same animal in a different color, and, see, long neck, bent tail, and no ears, um. Does this animal fit in? (blue, l. neck, s. ears, b. tail, varying color)

E: Uh. No this does not belong.

S: Well obviously the blue animal with the same characteristics doesn't fit in, so I will look for a brown animal, and see if that fits in. The same characteristics. Oh I mean a yellow animal. Does this animal fit in? (yellow, l. neck, s. ears, b. tail, varying color again)

E: No it does not belong.

S: Well that tells me that color is a characteristic that rules an animal out. Now I will look for the same animal with a straight tail. Does this animal fit in, the same color, but a straight tail? (brown, l. neck, s. ears, str. tail, varying only tail)

E: Which one? Yes that does belong.

S: So it does not matter if the tail is bent or straight. I will find one with a short neck. Does this animal fit in? (brown, s. neck, s. ears, str. tail, varying neck and tail)

E: Yes that does belong.

S: It doesn't matter if the neck is short or tall, but this animal does have short ears. I will find one with big ears. Does this animal fit in? (brown, l. neck, l. ears, str. tail, varying ears and tail)

E: No it does not.

S: Well I feel that the animal must be brown, and must have long or short neck, and must... Oh, I haven't tested for a curled tail yet. Does this animal fit in? (brown, s. neck, s. ears, curly tail, varying neck and tail again)

E: Yes it does belong.

S: Well then the animal must be brown, must have a long or short neck. Must have, well it doesn't matter what size neck, or what kind of tail it has, but it must have small ears.

E: O.K., that is correct. Um-hum. (*S* follows a conservative strategy and varies all the values of a 3-valued dimension)

Problem 4 (Concept is brown, short neck, straight tail)

E: This card belongs to the concept. What is the first thing you think of when I point a card out to you? (Focus card is brown, s. neck, s. ears, str. tail)

S: What do you mean the characteristics, or just the first...

E: Well the first thing you think of.

S: I think of a dachshund. It looks like a dachshund.

E: (Laughed) NO, I mean, you know,

S: Brown is the first thing, and the fact that it has a short neck, and no ears, so I think that is pretty important, and a straight tail and no other characteristics. Uh.

E: Then what do you think? Continue

S: I'm trying to decide, I'm looking for a card that's the exact same thing but a different color, and here is one in blue. (blue, s. neck, s. ears, str. tail)

E: No this does not belong.

S: Well I will find one in yellow and see if yellow belongs.

E: You usually test color first?

S: Yes I do. I think that is a good way to start anyway. I guess it really doesn't matter, it is the easiest, I feel, if you differentiate in color because then you can look for other characteristics. Does this animal, yellow one fit in? (yellow, s. neck, s. ears, str. tail)

E: No it does not belong.

S: That tells me that the animal that I'm looking for must be brown, so it narrows down the field, it is very easy to find animals by color rather than other characteristics, which aren't as visible. Uh. I'm checking the tail. Does this animal fit in? Oh wait, I'm sorry. I'm looking for a short neck. Does this animal fit in? (brown, s. neck, s. ears, b. tail, varying just tail)

E: No it does not belong.

S: Tells me that the tail must be straight. Does this animal fit in? The straight tail and long neck. (brown, l. neck, s. ears, str. tail, varying just neck)

E: What do you want to find out?

S: The neck.

E: No that does not belong.

S: It tells me that the neck must be short. Does this animal fit in? It has big ears. (brown, s. neck, l. ears, str. tail, varying just ears)

E: Yes it does belong.

S: Well that tells me that the animal must be brown, must have a straight tail, must have a short neck, and big ears. (*S* has just described the last card he has chosen.)

E: And big ears?

S: No, small ears. Oh wait it doesn't matter what ears.

E: O.K. That is correct.

Problem 5 (Concept is short ears)

E: This card belongs to the concept. (Focus card is blue, s. neck, s. ears, curly tail.

S: It is a blue animal with a curled tail, short neck, no ears. I'm going to check the color first so it is the same animal but a different color. (brown, s. neck, s. ears, c. tail, varying color)

E: Uh-hum. Yes it does belong.

S: Brown belongs, I'll see if yellow belongs too. (yellow, s. neck, s. ears, c. tail)

E: Yes that does belong.

S: Then that tells me that it doesn't matter what color it is. I will check for the tail first. Does this animal fit in? (yellow, s. neck, s. ears, b. tail, varying color and tail)

E: Yes that belongs too.

S: Well then that tells me that it doesn't matter if the tail is bent. Does this animal fit in? Let me see I'm looking for a curled tail. Oh wait that is a curled tail, I'm sorry, I'm looking for a small animal with a straight tail. Here it is. Does this animal fit in? (blue, s. neck, s. ears, str. tail, varying tail. Usually after checking both other values of color, *S* checks both other values of tail.)

E: Yes it does belong.

S: So that tells me that it doesn't matter what color it is or what kind of tail it has. Now I'm checking for a long neck. Does this animal fit in? Has a long neck. (yellow, l. neck, s. ears, c. tail)

E: Yes it does belong.

S: Then that tells me that it doesn't matter what neck it has. Does this animal fit in? (yellow, s. neck, l. ears, str. tail)

E: Why are you asking that?

S: It has the characteristics that are acceptable. But it has big ears, and I haven't checked for that yet.

E: No that does not belong.

S: That tells me that the animal may be any color, and that it may have any size neck, may have any kind of tail, but it must have small ears.

E: That is correct.

Problem 6 (Concept is curly tail)

E: That card belongs to the concept. (Focus card is brown, short neck, s. ears, c. tail)

S: That one.

E: Yea.

S: Uh. It has a short neck, small ears, and a curled tail, and it's brown. I will find the same thing in a different color. Lets see. Wait. Does this fit in? (blue, s. neck, s. ears, c. tail)

E: Yes it does belong.

S: Does this fit? (yellow, s. neck, s. ears, c. tail)

E: Yes it does.

S: That tells me that it doesn't matter what color is it. I'm looking for the size of the neck now. Does this fit in? (yellow, l. neck, s. ears, c. tail, varying color and neck)

E: Yes it does belong.

S: That tells me that it doesn't matter what size the neck is. Does this fit in? (yellow, s. neck, l. ears, str. tail, varying color, ears, and tail)

E: No that does not belong.

S: Ah wait that doesn't tell me anything because there are two different characteristics, I should have pointed to something else. Does this fit in? Oh wait, yea, Does this fit in? (blue, s. neck, l. ears, c. tail, varying color and ears)

E: What are you trying to find out?

S: What size the ears are.

E: Yea that belongs.

S: That tells me that it doesn't matter what size the ears are. Does this fit in? (blue, l. neck, l. ears, c. tail, varying everything except tail)

E: Yes that belongs.

S: Well thats for the long neck. Now have I tested for everything else? Does this fit in? (blue, l. neck, l. ears, b. tail, varying everything. *S* should have known the concept 2 choices ago.)

E: Which one, the blue one?

S: Yea.

E: No that does not belong.

S: Does this fit in, with the straight tail? (blue, s. neck, s. ears, str. tail, varying color and tail)

E: No that does not belong.

S: That tells me that I'm looking for an animal that can be of any color, can have any size neck or any size ears, but must have a curled tail.

E: That is correct. O.K. Tell me what your impression of this board is and the procedure and everything. Any thing you would like to comment about.

S: Uh-hum. I think it is a good way to test, well first of all the colors are good because I think you can differentiate between them pretty easily, and so that is the immediate stimulus I guess. The immediate thing that I see is a difference in color the first thing, and then if you distinguish between the colors first then you can find the different characteristics. It can be sort of confusing, forgetting if it has a bent tail, straight. I really don't see the purpose of it all. Unless it is an I.Q. or something.

E: Well this is just to see the little detailed thought processes that is behind solving problems like this.

S: Uh-hum.

E: That is all that you have to say on the subject?

S: Yea I think so.

E: What is your general strategy of solving the problem?

S: Well first I try to solve the problem with color. I think that it is easiest to differentiate, between colors, and then I usually look for neck first, and then, because that is another easy to differentiate because it is outstanding, and then for the tail, and the ears, it doesn't really matter which way you go about it because they are both equally as easy to see.

E: Uh-hum. O.K. That will be all for today. (*S* always picked color first. Then he would pick tail, not neck, in 2/3 of the problems. After that, neck, then ears. This *S* had been run initially on the old board of circles and triangles on colored paper. That is where he developed his conservative strategy. I ended this session early because *S* was getting very bored by that time.)

APPENDIX B
LISTING OF CASE MARK IV, MOD 2

```
              IPL LIST
                                        9
                                        2 A                  600
                                        2 C                  300
                                        2 D                  300
                                        2 E                  300
                                        2 F                  300
                                        2 G                  300
                                        2 K                  300
                                        2 L                  300
                                        2 M                  300
                                        2 N                  300
                                        2 O                  300
                                        2 P                  600
                                        2 Q                  300
                                        2 R                  300
                                        2 S                  300
                                        2 T                  300
                                        2 U                  300
                                        2 V                  300
                                        2 X                  300
                                        2 Z                  300
                                        5
    MARK 4 MOD 2 CONTEXTER              1
    U1 PROGRAM INTERPRETER              1
       EXECUTE RECURSION                 U1      9-1
       UNRECURSE FISRT RECURSION               309-7
       OUTPUT FINAL H5                         0199      0
    9-1 RECURSION ROUTINE               1
       PUSH DOWN RECURSE LIST LIKE H1    9-1   409-7
       SAVE ARG IN HEAD                        209-7
       BEGIN OR CONTINUE SCAN            9-5     9-3
       POP UP A LEVEL IF END LIST              700
       TEST FOR LOCAL SYMB               9-14  129-7
       IF YES THEN H5 DECISION JUMP              J132
       GOTO 9-4 IF DECISION JUMP               70        9-4
       CHECK FOR DESCRIBED ROUTINE             1297
       I.E. HAS A LOCAL HEAD                   52H0
       TEST                                      J132
       IF NOT EXECUTE THE SYMB                 709-6
                                               1297
                                                 J152
       YES GET ARGS FROM D-LIST                129-7
       COLLECT OUTPUT ARGS                       U3
       YES GET ARGS FROM D-LIST                129-7
                                                 U2
                                               1297
       CHECK FOR CONTEXT ROUTINE               10A6
                                                 J10
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57

```
  YES   GO TO 915                                70        915          49
  ENTER PR                                       1297                   50
```

IPL LIST

```
  RECURSE                                          9-1                  51
9-2 UNRECURSE                           9-2      309-7     9-5          52
915 EXECUTE CONTEXTER VIA U4            915      30H0                   53
  COPY CIA LIST                                  1097                   54
                                                   J73                  55
                                                   U4      95           56
9-7 H1 TYPE LIST                        9-7        0       0            57
  SAVE H5 OVER INTERPRETER              9-9        J4      0            58
9-3 SCAN ROUTINE                     1                                  59
  SCAN LIST NAMED IN HEAD OF 9-7        9-3      119-7                  60
  DOWN 1                                           J60                  61
  SAVE LOC AND EXIT                              2097      0            62
 94 DECISION BR. CHECK PREV H5          94       0199                   63
  IF H5 - TAKE THIS LOCAL                        709-12                 64
  SCAN                                             9-3                  65
  UNRECURSE IF END LIST                          700                    66
  IF YES RESET 9-7 HEAD                 9-12     129-7                  67
  WITHOUT RECURSION                              2097      95           68
 96 XEQ UNDESCRIBED PR (SET SIGN)       96       0199                   69
  ROUTINE , EXECUTE CURRENT ONE                  0297                   70
  SAVE H5 OVER INTERPRETER                       11H5                   71
  THIS ROUTINE TO BE TRACED                      2099                   72
                                                 10U5                   73
                                                 1297                   74
                                                   J77                  75
                                                 7095                   76
   NC
  PRINT NAME ,CONTENTS M1,M10                    10M1                   77
                                                 10J150                 78
                                                   J100                 79
                                                 10M10                  80
                                                   J152                 81
                                                 10M10                  82
                                                   J81                  83
                                                 7095                   84
                                                   J150    95           85
U5 TRACE LIST (USE NON DESCRIBED        U5         0       0            86
******'****************************1 ***** ********                     87
U2 COLLECT ARGS FROM D-LIST          1                                  88
  ARGUMENT 0 ATTRIBUTE                  U2       10A1                   89
  GET V-LIST OF ATT. A1                            J10                  90
  NONE EXIT                                      700                    91
  COLLECT ARGS                                   10J0      J100         92
******'****************************1 ***** ********                     93
U3 COLLECT OUTPUT ARGS FROM             U3       10A2                   94
  D-LIST                                           J10                  95
                                                 700                    96
                                                 10J0      J100         97
***********************************1 ***** ********                     98
U4 CONTEXTER EXECUTER                   U4         J44                  99
  SAVE COPY OF CIA LIST                          60W4                  100
```

IPL LIST

```
  GET LOC OF CONTEXTER                           52H0                  101
  GET CONTEXTER NAME                             52H0                  102
  SAVE IT                                        60W3                  103
  LOAD OUTPUT NAMES                                U3                  104
  LOAD INPUT NAMES                               11W3                  105
                                                   U2                  106
  ENTER CIA LIST NAME                            11W4                  107
  ENTER C NAME                                   11W3                  108
  GET EXECUTABLE CORE                              J81                 109
```

```
   EXECUTE IT                                  J1              110
   ERASE COPY CIA LIST                       11W4              111
                                               J71   J34       112
 **********************************1 *****  ********           113
 S2 CONSERVATIVE FOCUS STRATEGY        S2      90              114
   PROCESS FOCUS INFORMATION                   Z0              115
   CREATE WORKING HYP                          Z7              116
   DOUBLE DUMMY BR                             91              117
                                               91    0         118
   CREATE SEARCH CRIT                  91      0               119
                                               Z1              120
   LOCATE OBJ FROM EXT ENVIRONS                Z2              121
   HAVE EXPERIMENTOR DESIG. OBJ.               Z3              122
   PROCESS OBJ. DESIG. INFORMATION             Z4              123
   DETERMINE IF CONCEPT CAN BE GIVE            D1              124
                                NO             91              125
   YES CONTINUE                                93    0         126
   FORM CONCEPT                        93      0               127
   YES   FORMA CONCEPT                         Z5              128
   HAVE E DESIGNATE CONCEPT                    Z8              129
   DETERMINE IF CONCEPT CORRECT                D2              130
                                NO             92    0         131
   CORRECTIVE ACTION                   92      0               132
                                               Z6              133
   GIVE UP                                     D3              134
   NO,                                         91    0         135
                                      90       0     0         136
 **********************************1 *****  ********           137
 S1 STRAT SET IP                       S1      J0              138
                                             10M13             139
   MAKE M13 REFLECTIVE                         R39             140
   MAKE A3 LIST SYMMETRIC (UPPER)            10A3              141
                                               R39             142
                                      91       J140            143
                                             30H0              144
                                             11F5              145
                                             100               146
                                               J2              147
                                             70      J7        148
                                             10M10             149
                                               G30             150


               IPL LIST


                                             10M1              151
                                               G30             152
PUT                                          10M1              153
EXPERIMENTER MESSAGE                         10L60             154
IN M1                                          J65             155
  EXECUTE GENERAL STRAT                      10S3              156
                                               U1              157
  PRINT PROB HIST                              X20             158
  UNMARK DIMS AND VALS                       10M13             159
                                             10A5              160
                                               R38             161
                                               J0    91        162
**********************************1 *****  ********            163
X20 PRINT PROB. HISTORY               X20    11H5              164
  PRINT H5                                     J152            165
  PRINT CONCEPPT                             10M1              166
                                               J81             167
                                             7091              168
                                               J151            169
  PRINT STRAT L                       91     10M3              170
                                               J81             171
                                             40H0              172
                                               J150            173
  PRINT Z,P LEXVELS                                 10J150   U6           174
                                         97          0       0            175
**************************************1 ***** ********                    176
C12 POST MCRTEM ANALYSIS                 C12         J0                   177
  SET NOT FIRST PROB FLAG                           10L41                 178
                                                     J81                  179
                                                    10F2                  180
                                                    10A65                 181
                                                     J11                  182
                                                     J0      0            183
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S3 HIGH LEVEL CONTEXTING LIST            S3          90                   185
   TRASL EXPTR MESSAGES                              C11                  186
    EXPTR PRESENTS FOCUS                             E95                  187
    CREATE STRATEGY TO EXECUTE                       C61                  188
    POST MCRTUM ANALYSIS                             C12     0            189
                                         9C          0       0            190
******'*******************************1 ***** ********                    191
C11 TRANSLATE EXP INST INTO SSL          C11         90                   192
                                                     C10     0            193
                                         9C          0                    194
                                                     A1                   195
                                                     91      0            196
                                         91          0                    197
                                                     M1                   198
                                                     M10     0            199
**************************************1 ***** ********                    200


              IPL LIST

     SAVE MEP                            C10      30H0                    201
     GET NAME OF MESSAGE                           J81                    202
     LIST FROM M1                                 10C13     J100          203
**************************************1 ***** ********                    204
C13 CCNTRCL CONTEXTER                    C13       J43                    205
   (0) MESSAGE                                    60W3                    206
   COPY MESSAGE                                    J74                    207
                                                  40H0                    208
   DELETE A60 AND VALUE                           10A60                   209
   FRCM COPY                                       J14                    210
   SELECT PROPER CCNSTRUCTOR                      1097                    211
   VIA A60 VAL ON MESSAGE                         11W3                    212
   DESCRIPY                                       10A60                   213
                                                   G10                    214
   FRCM LIST 97                                    J10                    215
   EXIT IF NONE                                   70J33                   216
   EXECUTE CONTEXTER                               J1       J33           217
 97 LIST OF CONTEXTERS UNDER VALS 0      97        98       0             218
   OF A60                                98        0                      219
   PRCBLEM DETAILS                                 F61                    220
   CREATE PROB LIST ETC                            C50                    221
   PROCESS SPECIFICATION                           F62                    222
   CREATE SLELETAL PROCEDURE                       C51                    223
   ATTRIBUTE SPEC                                  F63                    224
   PLACE ATT ON LIST,SAVE VALUES                   C52                    225
   TERMINATION                                     F65                    226
   NORMAL EXIT                                     J0       0             227
**************************************1 ***** ********                    228
C50 CREATE PROB LIST AND ABSORB          C50       J47                    229
   PROB DETAILS(0) MESS SYMB                      60W7                    230
   SAVE NAME OF                                    J60                    231
   DDL WITH                                       52H0                    232
   PROB DETAILS                                   60W4                    233
   SAVE                                           10A50                   234
   VALUE OF                                        G10                    235
   A50=M13                                        20W2                    236
   PRCB LIST (L100)                                J90                    237
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    SAVE NAME                                   60W6               238
    EXTERNAL ENVIRONMENT                          J90              239
    E9                                          60W5               240
    PUT E9 ON L100                              10A300             241
                                                  J12              242
    PUT M13 ON E9                               11W5               243
                                                11W2               244
                                                10A50              245
                                                  J12              246
    PUT DDL                                     11W6               247
    ON PROB LIST (L100)                         11W4               248
                                                10A80              249
                                                  J12              250


                  IPL LIST

      GET DDL                                   11W4               251
      IS THIS                                   10A65              252
    PROBLEM                                       J10              253
    NOT IN                                      7093               254
      THE                                       10F1               255
      THE FIRST                                   J2               256
    PUT SKELETON                         93     11W6               257
      ONE ATTEMPTED                             7091               258
    STRAT ON PROB LIST                            J90              259
    (L100)                               92     60W3               260
                                                10A302             261
                                                  J12              262
      PLACE PROBLEM                             10M10              263
      LIST                                      11W6               264
      ON MEP                                      G2     J37       265
      NO,GET RSL FROM                    91     10M3               266
      M3 LIST                                     J81    92        267
*************************************1 ***** ********              268
C51 CREATE OPERATION SYMB FOR $SL        C51      J41              269
  (0)= LXX                                        J60              270
  GET 9-4 OFF LXX                               52H0               271
                                                20W0               272
  GET NAME OF                                   10M10              273
  SKEL STRAT LIST                                 J81              274
  UNDER A302                                    10A302             275
                                                  G10              276
  CREATE SYMBOL FOR Z LEVEL ROUTIN                J90              277
                                                60W1               278
  PUT NAME OF Z ON SSL                            J65              279
                                                11W1               280
                                                11W0               281
                                                10A3               282
                                                  J12    J31       283
*************************************1 ***** ********              284
C52 DESIGNATION INFORMATION              C52      J41              285
GET NAME OF CELL HOLDING DDL                      J81              286
  GET NAME OF 95                                52H0               287
  GET A7                                          J60              288
  SAVE NAME OF CELL HOLDING A7                  60W0               289
  GET VALUE NAME                                  J60              290
                                                52H0               291
                                                20W1               292
  PUT                                           10A15              293
  A7                                            12W0               294
  ON BODY OF A15                                  J65              295
                                                12W0               296
  PUT 930 ON                                    11W1               297
                                                  J73              298
  POSSIBLE VALUES OF                            10A111             299
                                                  J11    J31       300
```

```
           IPL LIST

  ************************************1 ***** ******** *
C101 FINDROUTINE ON (1) MATCHING     C101     J50
  DES OF (0) CLASS ATT A3                   1091
  GEN RSL CELLS (1)                           U6
  INVERT SIGN AND EXIT                        J5     J30
  SAVE PROCESS LOC FROM RSL          91     6097
  CHECK IF DESES MATCH                      11W0
  OF (0)=DES OF (0)                         10A3
                                              G210
  PICK UP LOC OF EQ P                       1197
  INVERT H5                                   J5
  EXIT                                      700      J8
 ************************************1 ***** ********
C61 CONSTUCT NEW STRAT               C61      90
                                              C60    0
                                     90       0
                                              A1
                                              91     0
                                     91       0
                                              M3
                                              M10    0
 C60 MAJOR CONTEXTER(0)M10(1)        C60      J46
   (1)RSL,  C(M10)=L100,SAVE INPUTS         20W0
                                            60W1
   GET RSL                                    J81
                                            20W6
   GET SSL FROM L100                        11W0
                                              J81
                                            10A302
                                              G10
   SAVE IT                                  20W3
   GET FERST PROB FLAG                      11W0
                                              J81
   UNDER A80 AND A65                        10A80
                                              G10
   NOT IN                                   7091
                                            10A65
                                              J10
   NOT IN                                   7091
   CHECK                                    10F1
                                              J2
                                            70       91
   NOT FIRST                                11W1
   XEQ RECENT (1 DOWN IN M3)                  J81
   EXECUTE RSL                                U1
   PUT NSL IN LTM (M3)               95     11W1
                                            11W6
                                              G4     J36
   FIST PROB                         91       J90
   SAVE SRTRAT AS CURRENT PHASE             60W2

           IPL LIST

   MAKE,SAVE NSL                            20W6
   GENERATE NO LINFK                          J90
                                              J136
   SAVE NO LINK                             60W4
   SAVE AS YES LINK (1ST TIME)              20W5
   GENSSL                                   11W3
                                            1092
                                              J100
   ERASE UMUSED YES NODE                    11W5
                                              J9     95
   LOCATE SSL SYMB DES               92     11W1
                                              J81
   ON RSL                                     J6
```

```
                                      C101                 364
   NCNE ERRCR                         7099                 365
   SAVE Z NAME                        60W3                 366
   ENTER PFASE LIST                   11W2                 367
   INVERT (C),(1)                      J6                  368
   ADC TO NSL                          J65                 369
   CFECK IF EXTERN INFO               11W3                 370
   CFECK FCR EXTERN INFO              10A31                371
                                       G10                 372
   NO                                 7094                 373
   OBJECT CCNTESTERS                  5097                 374
   CFECK IF OBJ DESIG                 11W3                 375
                                      10A33                376
                                       G10                 377
   NO,93                              7093                 378
   YES POP VAL                        30H0                 379
   ENTER CCNTEXT L                    50912                380
   ENTER INFO TYPE ATT         93     11W3                 381
   GET TYPE                           10A32                382
                                       G10                 383
                                      70        96         384
   POP CONTEXT LIST                   30H0      94         385
   GET PROPER CCNTEXTER        96      J10                 386
   NCNE ,94                           7094                 387
   DCUBLE NAME                        40H0                 388
   ADD A6 AND STRAT NAME              11W2                 389
                                      10A6                 390
                                       G11                 391
   ACC                                11W2                 392
                                       J6                  393
                                       J65                 394
   EXECUTE PHASE               910    11W2                 395
                                       U1                  396
   SAVE SIGN                   916    11H5                 397
                                      20917                398
   SAVE NAME OF PHASE XEQESD          11W2                 399
                                      20915                400
```

IPL LIST

```
   GET LAST SYMB                      11W2                 401
                                       J61                 402
                                      52H0                 403
   CFECK IF DECISION                  10A30                404
                                       G10                 405
   NO,EXIT                            70J4                 406
                                      10F31                407
                                       J2                  408
                                      70J4                 409
   YES, ADD NO LINK                   11W2                 410
                                      11W4                 411
                                       J65                 412
   ACC YES LINK                       11W2                 413
                                      11W5                 414
                                       J65                 415
   SET YES LINK AS CURRENT PHASE      11W5                 416
                                      20W2                 417
   GEN NEW YES LINJK                   J90                 418
                                       J136                419
                                      20W5                 420
   CFECK SIGN (U1)                    01917                421
   + EXIT                             70        0          422
   EXECUTE NO LINK IF -               11W4                 423
                                       U1       J4         424
   CHECK IF DECISION           94     11W3                 425
                                      10A30                426
                                       G10                 427
```

```
  NC EXIT                                      70J4                    428
  DECISIOM VAL                                 10F31                   429
                                                 J2                    430
  NO EXIT                                      70J4                    431
  YES CHECK IF PHASE ALREADY XEQED             11W2                    432
                                               11915                   433
                                                 J2                    434
  NO,910                                       70910                   435
  YES EXECUTE TEST AS SINGLE TON               11W3                    436
                                                 J91                   437
                                               60915                   438
  XEC TEAST                                      U1                    439
                                               11915                   440
  ERASE HOLDING CELLS                            J71    916            441
  ERROR                                99      10C60                   442
                                                 J152   J7             443
                                       917       0      0              444
                                       915       0      0              445
  TABLE FCR CONTEXTERS                 97        98     0              446
  PER INFO TYPE                        98        0                     447
  FOCUS                                          F51                   448
                                                 C21                   449
  OBJECT                                         F53                   450


                 IPL LIST

  OBJECT CHOICE                                  C37    0              451
  TABLE OF CONTEXTERS                  912       911    0              452
                                       911       0                     453
                                                 F53                   454
  OBJECT CESIG                                   C38                   455
  CCNCEPT                                        F54                   456
                                                 C23    0              457
*************************************1 ***** ********                  458
C21 Z7 CREATION                        C21       90                    459
    CIA INPUT ADDED BY U1                        C20    0              460
                                       90        0                     461
                                                 A3                    462
                                                 91     0              463
                                       91        0                     464
                                                 F32    0              465
C20 INITIALIZE Z7                      C20       J44                   466
    SAVE CIA                                   60W4                    467
                                               52H0                    468
  GET NEXT Z AFTER INTERUPT                      J81                   469
                                               7092                    470
  IF Z7 ON STRAT ,EXIT                         10Z7                    471
  PRCCESS CES ATT.                             10A3                    472
  CCMPARE                                        G210                  473
  YES EXIT                                     70        J34           474
  COPY DES Z7                          92      10Z7                    475
                                                 J74                   476
  SAVE                                         60W3                    477
  ERASE REMAINS AFTER HEAD                       G30                   478
  PUT NWE Z4 ON STRAT                  91      12W4                    479
                                               11W3                    480
                                                 J64                   481
  PHASE NAME ON SELF                           10C21                   482
    GET NAME OF PHASE                          10A6                    483
    LIST FROM                                    J10                   484
    VALUE LIST,OUTPUT IS PHASE SYM             20W1                    485
   COPY                                        11W3                    486
   P191                                        10P191                  487
   PUT IT CN =Z7=                                J65                   488
   PUT                                         11W3                    489
   P63                                         10P63                   490
   =Z7= BOCY                                     J65                   491
  PUT                                      11W3                 492
 C31                                       10C31                493
  =Z7= BODY                                  J65                494
  PUT                                      11W3                 495
  P64                                      10P64                496
  =Z7=                                       J65                497
   ADD                                     12W4                 498
   SYMBOL                                  10D4                 499
   TO PHASE 1 LIST                           J65                500
```

IPL LIST

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 DESCRIBE THAT                             11W1                 501
   Z7                                      11W3                 502
   ADDED TO PHASE 1 LIST                     C3                 503
   DESCRIBE THAT                           11W1                 504
   D4                                      10D4                 505
   ADDED TO PHASE 1 LIST                     C3      J34        506
************************************1 ***** ********            507
C37 VERIFY OBJECT CHOICE            C37      90                 508
    CIA INPUT VIA U1                         C36     0          509
                                    9C       0       0          510
C36 CREATE DO ROUTINE               C36      J44                511
    SAVE(CIA)=C37                          20W4                 512
    FIND                                   12W4                 513
    SYMBOL AFTER C37 ON                      J81                514
  STRAT LIST                               10D0                 515
    IS IT                                  10A3                 516
A DO TYPE ROUTINE                            G210               517
                                           70        J34        518
    CREATE                                 10D0                 519
    COPY                                     J74                520
    CF DO                                  60W3                 521
    ERASE BODY                               G30                522
    ADD                                    11W3                 523
    Q51                                    10Q51                524
    TO DO LIST                               J65                525
    ADD                                    12W4                 526
    DO                                     11W3                 527
  TO STRAT LIST                              J64                528
  GET PHASE L                              10C37                529
                                           10A6                 530
                                             J10                531
    DESCRIBE ADDITION OF                   11W3                 532
    PHASE LIST                               C3      J34        533
************************************1 ***** ********            534
C38 CREATE ROUTINE FOR Z4           C38      90                 535
    CIA INPUT VIA U1                         C39     0          536
                                    9C       0                  537
                                             A1                 538
                                             91      0          539
                                    91       0                  540
                                             M10     0          541
C39 CREATE REACTION TO OBJ DESIG    C39      J44                542
  SAVE CIA                                 20W4                 543
  SAVE MEP                                 20W0                 544
  GET PHASE L                              10C38                545
    GET                                    10A6                 546
    NAME                                     J10                547
    LIST AND SAVE IT                       20W1                 548
  COPY DES OF Z4                           10Z4                 549
                                             J74                550
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            IPL LIST

     SAVE                                      60W3                   551
     ERASE REMAINS AFTER HEAD                    G30                  552
     CHECK IF Z4 ON STRAT                      12W4                   553
     GET NEXT Z AFTER INTERUPT                   J81                  554
                                               7091                   555

     SAVE NAME                                 60W2                   556
     COPY OF Z4                                11W3                   557
     PROCESS DES ATT.                          10A3                   558
     COMPARE                                     G210                 559
     NO,CONTINUE                               7091                   560
     YES DELETE IT                             12W4                   561
     FROM STRAT                                11W2                   562
                                                 J69                  563

     ERASE Z4                                  11W2                   564
                                                 J72                  565

     PUT NWE Z4 ON STRAT                 91    12W4                   566
                                               11W3                   567

                                                 J64                  568
     STRAT LIST                                11W1                   569
     PUT DES OF CHANGE                         11W3                   570
     ON STRAT                                    C3                   571
     SET REVERT DV                             10P171                 572
                                               20W2                   573

        GET                                    11W0                   574
        DESIGNATION                              J81                  575
        OF                                     10A7                   576
        THE                                      G10                  577
        OBJECT                                 10F1                   578
        CHOSEN                                   J2                   579
                                               7093                   580

     SET REMOVE DV                             10P101                 581
                                               20W2       94          582
                                         93    10L9                   583
        SUBJECT                                10A91                  584
        AWARE                                    G10                  585
        OF                                     10F7                   586
        DIMENSIONS VARIED                        J2                   587
        NO,TO CREATE Z4,YES=CONTINUE           7094                   588
        WAS                                    10K98                  589
        ONE                                    10K1                   590
     DIMS CONC VARIED                            J114                 591
        NO,CREATE NULL Z4,YES CREATE Z         70         94          592
        ADD                                    11W3                   593
        C4U                                    10C41                  594
        TO NULL Z4                               J65      92          595
     ADD P502 TO Z4                      94    11W3                   596
                                               10C41                  597

                                                 J65                  598
     MARK DIM VALS                             11W3                   599
                                               10P96                  600


            IPL LIST

                                                 J65                  601
      INSERT                                   11W3                   602
      P91( MARK DIMENSIONS)                    10P91                  603
      ON =Z4=                                    J65                  604
     ADD C41 TO Z4                             11W3                   605
                                               10P502                 606
                                                 J65                  607
     ADD P101 OR P171 TO Z                     11W3                   608
                                               11W2                   609
                                         97      J65                  610
     EXIT                                92      J0       J34         611
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*********************************1 ***** ********            612
C23 SET UP REACTION  TO CONCEPT DES  C23    90                613
                                            C22     0         614
                                     90     0       0         615
C22 SET UP =Z6=,REACT TO CONCEPT     C22    J44               616
  TO OBJECT DESIGNATION                   20W4                617
  CFECK IF Z4 ON STRAT                    12W4                618
  GET NEXT Z AFTER INTERUPT                 J81               619
  GO TO 91 IF NOTHIG                      7091                620
  SAVE NAME                               60W2                621
  CFECK IF Z6 THERAE                      10Z6                622
  PROCESS DES ATT.                        10A3                623
  CCMPARE                                   G210              624
  NO,CONTINUE                             7091                625
  YES DELETE IT                           12W4                626
  FRCM STRAT                              11W2                627
                                            J69               628
  ERASE Z4                                11W2                629
                                            J72               630
   GET                               91   10M1                631
   CONCEPT                                  J81               632
   CHECK                                  10A27               633
   IF                                       G10               634
  IF NONE ERROR                           7099                635
   IT IS                                  10F1                636
   A YES                                    J2                637
                                          7092      J34       638
  COPY DES OF Z6                     92   10Z6                639
                                            J74               640
  SAVE                                    60W3                641
  ERASE REMAINS AFTER HEAD                  G30               642
  PUT NWE Z4 ON STRAT                     12W4                643
                                          11W3                644
                                            J64               645
  GET PHASE L                             10C23               646
                                          10A6                647
                                            J10               648
  PUT DES OF CHANGE                       11W3                649
  ON STRAT                                  C3                650


              IPL LIST

 GET FOCUS OBJECT                         11F6                651
  OBJECT                                  60W1                652
  TEST                                    10A5                653
  IF                                        R41               654
  ANY                                       J78               655
 SET Z6 TC FIND UNMARKED DIMS             10Q41               656
                                          70        93        657
 SET Z6 TC FIND IRREL DIMS                50Q42               658
                                     93   20W0                659
  PUT                                94   11W3                660
  C41                                     10C41               661
  CN =Z6=                                   J65               662
  PUT                                     11W3                663
  C41                                     10C41               664
  CN=Z6=                                    J65               665
  PUT                                     11W3                666
 PUT Q41 OR Q42                           11W0                667
  CN =Z6=                                   J65               668
  PUT                                     11W3                669
  P181                                    10P181              670
  CN =Z6=                                   J65               671
  PUT                                     11W3                672
  P64                                     10P64               673
 ON Z6                                      J65               674
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    IS                                             10L9                675
    SUBJECT                                        10A91               676
    AWARE                                            G10               677
                                                   10F7                678
                                                     J2                679
                                                   70          96      680
    FOCUS OBJECT                                   11W1                681
    COUNT DIMENSIONALITY OF FOCUS                    J126      97      682
                                          96       10K1                683
    SET VALUE OF                          97         J120              684
    K96 ON                                         11W3                685
    QW41,P181                                        J6                686
    TO VALUE OF  K                                   C8        J34     687
   ERROR                                  95       10C23               688
                                                     J152      J7      689
 ************************************1 ***** ********                  690
 C8 SET DATA TERMS IN INPUTS OF           C8         J50               691
   ROUTINES ON (1) TO VAL (0)                      1091                692
   GEN P ROUTINES                                    U6        J30     693
   ENTER S FROM GENED CALL                91       52H0                694
   GET INPUT PARAMS                                10A1                695
                                                     J10               696
   NONE EXIT                                       70J4                697
   MOVE DOWN LIST OF INPUTS               95         J60               698
   SAVE LOC                                        2097                699
   EXIT IF END                                     70J4                700


                IPL LIST

    CHECK IF DATA TERM                             1297                701
                                                     J131              702
    NO CONTINUE                                    7093                703
    YES REPLACE BY (0)                             11W0                704
                                                   2197                705
    CONTINUE                              93       1197        95      706
                                          97         0         0       707
  ************************************1 ***** ********                 708
 C3 DESCRIBE CHANGE (TO)                  C3         J50               709
    (0 Z,(1)STRAT                                  40H0                710
    MAKE DDL WITH S AS DIM                         10A9                711
    AND A9                                           U20               712
    DOUBLE NAME OF DDL                             40H0                713
    DESCRIBE Z ADDED AS (TO) CHANGE                11W0                714
                                                   10A11               715
                                                     J12               716
    PUT DDL ON S                                   10A12               717
    UNDER CLASS ATT                                  J12       J30     718
  ************************-***********1 ***** ********                 719
  Z0 PROBLEM SPECIFICATIONS               Z0         9-0               720
    COPY FOCUS                                       P21               721
    REMEMBER CFO ON PROB LIST                        P61               722
    PUT COPY OF FOCUS ON MEP                         C31               723
    REMEMBER SET MEMBERSHIP OF CFO                   P62       0       724
    DESCRIP3ION OF PROCESS                9C         0                 725
    GENERAL DESCRIPTION                              A3                726
                                                     93        0       727
                                          93         0                 728
                                                     94        0       729
                                          94         95        0       730
                                          95         0                 731
    TYPE OF PROCESS                                  A30               732
                                                     96                733
    COMMUNICATION                                    A31               734
                                                     97                735
    INFORMATION CREATED                              A32               736
                                                     98                737
    DESIGNATION INFO                                 A33               738
```

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                                              99     0          739
    VALUE OF A30                        96    0                 740
      DOING                                   F30    0          741
    VALUE OF A31                        97    0                 742
      FROM EXTERNAL                           F41    0          743
    VALUE OF A32                        98    0                 744
      FOCUS OBJECT                            F51    0          745
                                        99    0      0          746
 ***********************************1 ***** ********            747
 Z7 CREATE SEARCH CRITERION             Z7    90                748
    CREATE WCRKING HYP FRCM CFO               P191              749
    REMEMBER WH                               P63               750

                  IPL LIST

   PUT WH ON MEP                              C31               751
   REMEMBER WHAT WH MADE FROM                 P64    0          752
   DESCRIPTION CF PROCESS               90    0                 753
   GENERAL DESCRIPTION                        A3                754
                                              93     0          755
                                        93    0                 756
                                              94     0          757
                                        94    95     0          758
                                        95    0                 759
   TYPE OF PROCESS                            A30               760
                                              96                761
   COMMUNICI ION                              A31               762
                                              97                763
   INFORMATION CREATED                        A32               764
                                              98                765
   DESIGNATION INFC                           A33               766
                                              99     0          767
   VALUE OF A30                         96    0                 768
     COING                                    F30    0          769
                                        97    0      0          770
   VALUE OF A32                         98    0                 771
     FOCUS OBJECT                             F51    0          772
                                        99    0      0          773
***********************************1 ***** ********             774
D4 PROCEED FROM PHASE 2 FROM 3NE        D4    90                775
                                              D40    0          776
                                        90    0                 777
                                              A3                778
                                              93     0          779
                                        93    0                 780
                                              94     0          781
                                        94    95     0          782
                                        95    0                 783
                                              A30               784
                                              96                785
                                              A31               786
                                              97                787
                                              A32               788
                                              98                789
                                              A33               790
                                              99     0          791
                                        96    0                 792
                                              F31    0          793
                                        97    0      0          794
                                        98    0                 795
                                              F53    0          796
                                        99    0      0          797
D40                                     D40   J4     0          798
***********************************1 ***** ********             799
Z1 FORM OBJECT SELECTION CRIT           Z1    90                800
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             IPL LIST

      SELECT DIMS TO VARY                          P131            801
      VARY DIMS SELECTED                           P141            802
      MODIFY WH INTO SEARCH CRITERION              P151            803
      REMEMBER HOW WH MODIFIED                     P64    0        804
      DESCRIPTION OF PROCESS          9C           0               805
      GENERAL CESCRIPTION                          A3              806
                                                   93     0        807
                                      93           0               808
                                                   94     0        809
                                      94           95     0        810
                                      95           0               811
      TYPE OF PROCESS                              A30             812
                                                   96              813
      CCMMUNICATION                                A31             814
                                                   97              815
      INFORMATION CREATED                          A32             816
                                                   98              817
      DESIGNATION INFO                             A33             818
                                                   99     0        819
      VALUE OF A30                    96           0               820
        COING                                      F30    0        821
                                      97           0      0        822
      VALUE OF A32                    98           0               823
        SEARCH CRITERION                           F52    0        824
                                      99           0      0        825
***********************************1 ***** ********                826
Z2 SELECT AN OBJECT                   Z2           9-0             827
      THAT AGREES WITH FOCUS AND                   P51             828
      REMEMBER OBJECT FOUND                        P65             829
      PUT OBJ CN MEP                               C31             830
      REMEMBER HOW OBJ FOUND                       P66    0        831
      DESCRIPTION OF PROCESS          9C           0               832
      GENERAL CESCRIPTION                          A3              833
                                                   93     0        834
                                      93           0               835
                                                   94     0        836
                                      94           95     0        837
                                      95           0               838
      TYPE OF PROCESS                              A30             839
                                                   96              840
      CCMMUNICATION                                A31             841
                                                   97              842
      INFORMATION CREATED                          A32             843
                                                   98              844
      DESIGNATION INFO                             A33             845
                                                   99     0        846
      VALUE OF A30                    96           0               847
        DOING                                      F30    0        848
      VALUE OF A31                    97           0               849
        FROM EXTERNAL                              F41    0        850

             IPL LIST

      VALUE OF A32                    98           0               851
        CBJECT CHOICE                              F53    0        852
                                      99           0      0        853
***********************************1 ***** ********                854
DO VERIFY OBJ CHOICE                  DC           90              855
                                                   Q51    0        856
                                      9C           0               857
                                                   A3              858
                                                   93     0        859
                                      93           0               860
                                                   94     0        861
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                                  94      95      0        862
                                  95      0                863
                                          A30              864
                                          96               865
                                          A31              866
                                          97               867
                                          A32              868
                                          98               869
                                          A33              870
                                          99      0        871
                                  96      0                872
                                          F31     0        873
                                  97      0       0        874
                                  98      0                875
                                          F51     0        876
                                  99      0       0        877
 Q51 VERIFY OBJ CHOICE            Q51     90               878
                                          Q50     0        879
                                  90      0                880
                                          A1               881
                                          91               882
                                          A2               883
                                          92      0        884
                                  91      0                885
                                          M10     0        886
                                  92      0                887
                                          H5      0        888
 Q50 CHECK OBJECTS CHOICE         Q50     J6               889
                                          J51              890
   GET OBJ                              11W1               891
   GET OBJ                                J81              892
                                        60W1               893
   GET FOCUS                            11F6               894
   F-O                                    R3               895
                                        20W0               896
   GET LIST                             11W1               897
                                        10A26              898
                                          G10              899
                                        70J31              900


              IPL LIST

   (TO) DES                             10A11              901
                                          G10              902
                                        11W0               903
                                        7092               904
   FOCUS-O)-(TO LIST)                     R3               905
                                        11W0               906
                                          J71              907
   CHECK IF VALS ON                     40H0               908
   (F-O)-(TO) ARE MARKED                109[illegible]     909
                                          J100             910
                                  92      J4               911
   ERASE                                  J71     J31      912
   CHECK IF VALS MARKED           91    10A5               913
                                          R81              914
                                        700       J8       915
*************************************** ***** ********     916
 Z3 HAVE EXPERIMENTER DESIGNATE IT  Z3    9-0              917
   TRANSFER OBJ NAME FROM MEP TO E1       P71              918
   EXPERIMENTOR DESIGNATES OBJ            E93              919
   REMEMBER DESIG. (SET)                  P62     0        920
   DESCRIPTION OF PROCESS         90      0                921
   GENERAL DESCRIPTION                    A3               922
                                          93      0        923
                                  93      0                924
```

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                                                94    0            925
                                       94       95    0            926
                                       95       0                  927
    TYPE OF PROCESS                             A30                928
                                                96                 929
    COMMUNICATION                               A31                930
                                                97                 931
    INFORMATION CREATED                         A32                932
                                                98                 933
    DESIGNATION INFO                            A33                934
                                                99    0            935
    VALUE OF A30                       96       0                  936
      DOING                                     F30   0            937
    VALUE OF A31                       97       0                  938
      BOTH                                      F42   0            939
    VALUE OF A32                       98       0                  940
      OBJECT CHOICE                             F53   0            941
    VALUE OF A33                       99       0                  942
      OBJECT                                    F71   0            943
 *************************************1 ***** ********             944
 Z4  PROCESS OBJ DESIG. INFO.          Z4       90                 945
    RECALL SET MEMBERSHIP OF OBJ                P501               946
    POP MEP                                     C41                947
    FLAG DIM AND VALUES                         P91                948
    REVERT DIM VALS ON WH                       P171               949
    REMEMBER CHANGE IN S.C.                     P64   0            950


               IPL LIST

    DESCRIPTION OF PROCESS             90       0                  951
    GENERAL D5SCRIPTION                         A3                 952
                                                93    0            953
                                       93       0                  954
                                                94    0            955
                                       94       95    0            956
                                       95       0                  957
    TYPE OF PROCESS                             A30                958
                                                96                 959
    COMMUNICATION                               A31                960
                                                97                 961
    INFORMATION CREATED                         A32                962
                                                98                 963
    DESIGNATION INFO                            A33                964
                                                99    0            965
    VALUE OF A30                       96       0                  966
      DOING                                     F30   0            967
                                       97       0     0            968
                                       98       0     0            969
    VALUE OF A33                       99       0                  970
      OBJECT                                    F71   0            971
 *************************************1 ***** ********             972
 D1 CAN A CONCEPT BE PRESENTED         D1       90                 973
                                                Q101  0            974
    DESCRIPTION OF PROCESS             90       0                  975
    GENERAL DESCRIPTION                         A3                 976
                                                93    0            977
                                       93       0                  978
                                                94    0            979
                                       94       95    0            980
                                       95       0                  981
    TYPE OF PROCESS                             A30                982
                                                96                 983
    COMMUNICATION                               A31                984
                                                97                 985
    INFORMATION CREATED                         A32                986
                                                98                 987
    DESIGNATION INFO                            A33                988
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                                                  99      0        989
    VALUE OF A30                         96       0                990
      DECIDING                                    F31     0        991
                                         97       0       0        992
    VALUE OF A32                         98       0                993
      CONCEPT                                     F54     0        994
                                         95       0       0        995
  ***********************************1 ***** ********              996
  Z5 FORM CONCEPT, HAVE EXPERIMENTER     Z5       9-0              997
    FORM CONCEPT                                  P121             998
    REMEMBER CONCEPT                              P67              999
    PUT CONCEPT ON MEP                            C31             1000

                 IPL LIST

    REMEMBER HOW CONCEPT FORMED                   P68     0       1001
    DESCRIPTION OF PROCESS               90       0               1002
    GENERAL DESCRIPTION                           A3              1003
                                                  93      0       1004
                                         93       0               1005
                                                  94      0       1006
                                         94       95      0       1007
                                         95       0               1008
    TYPE OF PROCESS                               A30             1009
                                                  96              1010
    COMMUNICA3ION                                 A31             1011
                                                  97              1012
    INFORMATION CREATED                           A32             1013
                                                  98              1014
    DESIGNATION INFO                              A33             1015
                                                  99      0       1016
    VALUE OF A30                         96       0               1017
      DOING                                       F30     0       1018
                                         97       0       0       1019
    VALUE OF A32                         98       0               1020
      CONCEPT                                     F54     0       1021
                                         95       0       0       1022
  ***********************************1 ***** ********             1023
  Z8  HAVE E DESIGNATE CONCEPT           Z8       90              1024
    NAME OF CONCEPT TO E                          P72             1025
    E DESIGNATE CONCEPT                           E94             1026
    REMEMBER DESIGNATION OF CONCEPT               P69     0       1027
    DESCRIPTION OF PROCESS               90       0               1028
    GENERAL DESCRIPTION                           A3              1029
                                                  93      0       1030
                                         93       0               1031
                                                  94      0       1032
                                         94       95      0       1033
                                         95       0               1034
    TYPE OF PROCESS                               A30             1035
                                                  96              1036
    COMMUNICATION                                 A31             1037
                                                  97              1038
    INFORMATION CREATED                           A32             1039
                                                  98              1040
    DESIGNATION INFO                              A33             1041
                                                  99      0       1042
    VALUE OF A30                         96       0               1043
      DOING                                       F30     0       1044
    VALUE OF A31                         97       0               1045
      BOTH                                        F42     0       1046
    VALUE OF A32                         98       0               1047
      CONCEPT                                     F54     0       1048
    VALUE OF A33                         95       0               1049
      CONCEPT                                     F72     0       1050
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              IPL LIST

  *************************************1 ***** ********             1051
  D2 DETERMINE CONCEPT DESIGNATION     D2      90                   1052
                                               P501                 1053
     DETERMIN5 IF CONCEPT CORRECT              Q12     0            1054
     DESCRIPTION OF PROCESS            9C      0                    1055
     GENERAL DESCRIPTION                       A3                   1056
                                               93      0            1057
                                       93      0                    1058
                                               94      0            1059
                                       94      95      0            1060
                                       95      0                    1061
     TYPE OF PROCESS,                          A30                  1062
                                               96                   1063
     COMMUNICATION                             A31                  1064
                                               97                   1065
     INFORMATION CREATED                       A32                  1066
                                               98                   1067
     DESIGNATION INFO                          A33                  1068
                                               99      0            1069
     VALUE OF A30                      96      0                    1070
       DECIDING                                F31     0            1071
                                       97      0       0            1072
     VALUE OF A32                      98      0                    1073
       CONCEPT                                 F54     0            1074
     VALUE OF A33                      99      0                    1075
       CONCEPT                                 F72     0            1076
  *************************************1 ***** ********             1077
  Z6 CORRECTIVE ACTION                 Z6      90                   1078
     POP MEP TO WH                             C41                  1079
                                               C41                  1080
     FIND UNTESTED DIM VAL(S)                  Q41                  1081
                                               91                   1082
     SOME                                      92      0            1083
     NONE EXIT                         91      R0      0            1084
     BR (+)                            92      0                    1085
     ADD DIMS TO WH                            P181                 1086
     PUT NEW WH ON MEP                         C31                  1087
     REMEMBER HOW NEW WH FORMED                P64     0            1088
     DESCRIPTION OF PROCESS            9C      0                    1089
     GENERAL DESCRIPTION                       A3                   1090
                                               93      0            1091
                                       93      0                    1092
                                               94      0            1093
                                       94      95      0            1094
                                       95      0                    1095
     TYPE OF PROCESS                           A30                  1096
                                               96                   1097
     COMMUNICATION                             A31                  1098
                                               97                   1099
     INFORMATION CREATED                       A32                  1100

              IPL LIST

                                               98                   1101
     DESIGNATION INFO                          A33                  1102
                                               99      0            1103
     VALUE OF A30                      96      0                    1104
       DOING                                   F30     0            1105
                                       97      0       0            1106
     VALUE OF A32                      98      0                    1107
       SEARCH CRITERION                        F52     0            1108
                                       99      0       0            1109
  *************************************1 ***** ********             1110
  D3 GIVE UP                           D3      90                   1111
```

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                                                         J0     0       1112
     DESCRIPTION OF PROCESS                90            0              1113
     GENERAL DESCRIPTION                                 A3             1114
                                                         93     0       1115
                                           93            0              1116
                                                         94     0       1117
                                           94            95     0       1118
                                           95            0              1119
     TYPE OF PROCESS                                     A30            1120
                                                         96             1121
     COMMUNICA3ION                                       A31            1122
                                                         97             1123
     INFORMATION CREATED                                 A32            1124
                                                         98             1125
     DESIGNATION INFO                                    A33            1126
                                                         99     0       1127
     VALUE OF A30                          96            0              1128
       DECIDING                                          F31    0       1129
                                           97            0      0       1130
     VALUE OF A32                          98            0      0       1131
     VALUE OF A33                          99            0      0       1132
***********************************1 ***** ********                     1133
     EXIT (DO NOTHING)                     R0            90             1134
                                                         J0     0       1135
                                           90            0      0       1136
***********************************1 ***** ********                     1137
E95 PRESENT FOCUS OBJ TO SUBJECT           E95           90             1138
                                                         E2     0       1139
                                           90            0              1140
                                                         A1             1141
                                                         91             1142
                                                         A2             1143
                                                         92     0       1144
                                           91            0              1145
     CONTAINS NAME OF FOCUS OBJ                          F6     0       1146
                                           92            0              1147
     CONTAINS NAME AND DESIG OF F OBJ                    M1     0       1148
E2 EXPERIMENTER PUT FOCUS                  E2            J51            1149
     CLEAR                                             11W1             1150


                  IPL LIST

    M1                                                   G30            1151
    AND DESCRIPTION ON STM (M1)                        11W1             1152
    DESCRIBE FOCUS AS YES                              10F1             1153
                                                         J91            1154
                                                         J136           1155
    ATTACH DESCRIPTION                                 10A7             1156
    MAKE DESCRIPTION                                     U20            1157
    PUT DESCRIPTION ON M1 STM                            G2             1158
    ENTER STM (M1)                                     11W1             1159
    ENTER FOCUS                                        12W0             1160
    PUT OBJECT ON STM                                    G2     J31     1161
************************************1 ***** ********                    1162
P21 COPY AND PUTBACK THE 1ST ITEM          P21           9-0            1163
                                                         P20    0       1164
                                           9-0           0              1165
                                                         A2             1166
                                                         9-2            1167
                                                         A1             1168
                                                         9-1    0       1169
                                           9-1           0              1170
                                                         M1     0       1171
                                           9-2           0              1172
                                                         M1     0       1173
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P20 MAKE COPY OF LIST STRUCTURE        P20        J51                     1174
   IN (0) AND REPLACE TOP              9-2      11W1                      1175
   PUT NAME OF COPY BACK IN M1                  11W0                      1176
    GET HYP                                       G1                      1177
   SAVE NAME                                    40H0                      1178
   GET DIM VAL                                    G1                      1179
   GET DIM                                      10A6                      1180
                                                  G10                     1181
   GET M13                                      10A6                      1182
                                                  G10                     1183
   (0)FOCUS,(1)M13                                J6                      1184
   MAKE CFO IN DAV ORDER                          R190                    1185
   MAKE LOCAL                                     J136                    1186
                                                  G4       J31            1187
*************************************1 ***** ********                     1188
P191 CREATE INITIAL HYPOTHESIS         P191       90                      1189
                                                  P190     0              1190
                                       9-0        0                       1191
                                                  A2                      1192
                                                  9-2                     1193
                                                  A1                      1194
                                                  9-1      0              1195
                                       9-1        0                       1196
                                                  M10                     1197
                                                  K99      0              1198
                                       9-2        0                       1199
                                                  M1       0              1200


                  IPL LIST

 P190 MAKE K99 DIM ED S.C.              P190      J50                     1201
    (0)K99,(1)M10,(2)M1                           G1                      1202
    GET CFO COPY SAVE                             R73                     1203
                                                6097                      1204
    FIND K99TH ELEMENT ON CFO                   11W0                      1205
                                                  J200                    1206
    CUT LIST                                      J75                     1207
                                                  J136                    1208
    DOUBLE NAME OF REMAINS                      40H0                      1209
    COLLECT DIMS OF REMAINS                       R6                      1210
    MAKE FOM TO D-LIST                          10A9                      1211
    WITH DIMS VARIED                              U20                     1212
    SAVE DDL                                    60W0                      1213
    ARTTACH                                       J6                      1214
    DIM VALS FROM                               10A10                     1215
    TO DDL                                        J11                     1216
    CLEAR M1                                    40H0                      1217
                                                  G30                     1218
    PUT DDL                                     40H0                      1219
    INM1                                        11W0                      1220
                                                  G2                      1221
    PUT S.C.                                    1197                      1222
    IN M1 EXIT                                    G2       J30            1223
                                        97        0        0              1224
  *************************************1 ***** ********                   1225
  P131 SELECT A DIM TO VARY             P131      9-0                     1226
                                                  P130     0              1227
                                        9-0       0                       1228
                                                  A2                      1229
                                                  9-2                     1230
                                                  A1                      1231
                                                  9-1      0              1232
                                        9-1       0                       1233
                                                  M10                     1234
                                                  K98      0              1235
                                        9-2       0                       1236
                                                  M1       0              1237
  P130 SELECT DI TO VARY             P130      J44                  1238
    (0)NO. TC VARY,(1)MEP,(2)M1               20W0                  1239
    GET S.C.                                    G1                  1240
    CCLLECT DIM VALS                          60W3                  1241
    NOT DESIG ED                              10A5                  1242
                                                R41                 1243
    SAVE LIST                                 60W1                  1244
    CUT OFF LIST                              11W0                  1245
    AFTER 1W0                                   J200                1246
    ERASE REMAINS                               G30                 1247
                                              11W1                  1248
    CCLLECT DIMS                                R6                  1249
    MAKE DDL                                  10A9                  1250

               IPL LIST

    OF DIMS (TO VARY)                           U20                 1251
                                              60W2                  1252
    ACC DIM VALS LIST                         11W1                  1253
    TO DDL                                    10A10                 1254
                                                J11                 1255
    CLEAR M1                                  40H0                  1256
                                                G30                 1257
    PUT DDL  IN M1                            40H0                  1258
                                              11W2                  1259
                                                G2                  1260
    PUT S.C. IN M1                            11W3                  1261
                                                G2      J34         1262
 ************************************1 *****  ********               1263
  P141 VARY SELECTED DIMENSION       P141       9-0                 1264
                                                P140    0           1265
                                     9-0        0                   1266
                                                A2                  1267
                                                9-2                 1268
                                                A1                  1269
                                                9-1     0           1270
                                     9-1        0                   1271
                                                M1      0           1272
                                     9-2        0                   1273
                                                M1      0           1274
  P140 GET (CHANGE TO DIM VALS)      P140       J45                 1275
    (0) M1,(1)M1                              20W5                  1276
    GET DDL                                     J82                 1277
    SAVE NAME                                 60W4                  1278
    GET (CHANGE FROM) DIM VALUES              10A9                  1279
                                                J10                 1280
                                              70J45                 1281
    GET DIMS VARIED                           11W4                  1282
                                              10A10                 1283
                                                J10                 1284
    GENERATE IN PARALLEL                      1091                  1285
                                                R100    J35         1286
    SAVE CIM AND DIM VALS            91         J51                 1287
    DIM                                       11W1                  1288
    GET PREF ORDER LIST                       10A8                  1289
                                                G10                 1290
    SAVE                                      60W1                  1291
    SET PROB OF FOCUS DIM VAL -               11W0                  1292
                                                G9                  1293
    CHOOSE DIM VAL                   93       11W1                  1294
                                                R52                 1295
    NCNE EXIT                                 70J31                 1296
    SAVE VAL                                  60W2                  1297
    CECK IF CISIG                             10A5                  1298
                                                G10                 1299
    NO                                        7092                  1300
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                IPL LIST

    YES PICK ANOTHER                              30H0     93          1301
    ADD (CHANGE TO) ATT                    92     11W4                 1302
    AND VAL TO DDL                                11W2                 1303
                                                  10A11                1304
                                                    J12                1305
    SET SIGN                                      11W1                 1306
    (TO) VAL +                                    11W2                 1307
                                                    J10                1308
                                                    J122               1309
                                                  30H0                 1310
    SET SIGN (FROM)                               11W1                 1311
    PROB +                                        11W0                 1312
                                                    J10                1313
                                                    J122               1314
                                                  30H0                 1315
                                                    J4     J31         1316
**************************************1  *****  ********               1317
P151 VARY THE HYPOTHESIS                 P151       9-0                1318
                                                    P150   0           1319
                                         9-0      0                    1320
                                                    A2                 1321
                                                    9-2                1322
                                                    A1                 1323
                                                    9-1    0           1324
                                         9-1        0                  1325
                                                    M1     0           1326
                                         9-2        0                  1327
                                                    M1     0           1328
P150 VARY SEARCH CRITERION               P150       J42                1329
                                                  20W0                 1330
     FROM A10 VALUE TO A11 VALUE                    G1                 1331
     INPUT (0) M1                                 20W2                 1332
     SAVE S.C. GET DESCRIPT                       11W0                 1333
                                                    J82                1334
     SAVE                                         60W1                 1335
     GET CHANGE                                   10A10                1336
     FROM LIST                                      J10                1337
     ERROR                                        70J32                1338
     GET (CHANGE TO) LIST                         11W1                 1339
                                                  10A11                1340
                                                    J10                1341
     GENERATE BOTH IN PARALLEL                    1091                 1342
                                                    R100               1343
                                                    J4     J32         1344
     CHANGE SEARCH CRITERION             91         J51                1345
     REPLACE CHANGE FROM                          11W2                 1346
     DIM VAL BY CHANGE TO                         11W1                 1347
                                                  11W0                 1348
                                                    J31                1349
     POP                                            J67    J4          1350

                IPL LIST

**************************************1  *****  ********               1351
P51 LOCATE OBJ. VIA SEL. CRITERIA        P51        9-0                1352
                                                    P50    0           1353
                                         9-0        0                  1354
                                                    A2                 1355
                                                    9-2                1356
                                                    A1                 1357
                                                    9-1    0           1358
                                         9-1        0                  1359
                                                    M10                1360
                                                    E0     0           1361
                                         9-2       0                1362
                                                   M1     0         1363
P50 SEARCH FOR OBJ MATCHING HYP          P50       J52              1364
  GET CURRENT HYP                                11W1               1365
                                                   G1               1366
  SAVE NAME                                      20W1               1367
  (0)E0,(1)M10,(2)M1                     91      11W0               1368
  HYP                                            11W1               1369
  SEARCH BOARD FOR OBJECT                          R2               1370
  MATCHING CURRENT HYP                           70J32              1371
  SAVE OBJECT NAME                               20W0               1372
  CLEAR MZ1                                      11W2               1373
                                                   G30              1374
  ENTER HYP NAME                                 11W1               1375
  PUT S.C.                                       10A12              1376
  FRCM TO ATTS.                                    G10              1377
  ON OBJECT CHOICE                                 J74              1378
                                                   J136             1379
  PLACE OBJECT                                   11W2               1380
  DESCRIPTION                                      J6               1381
  ON STM (1W2)                                     G2               1382
  PLACE OBJECT                                   11W2               1383
  LOC                                            12W0               1384
  COPY OBJ.                                        R73              1385
  ON STM.EXIT                                      G2     J32       1386
******'********************************1 ***** ********             1387
P61 ATTACH CFO TO PROB LIST              P61       90               1388
                                                   P60    0         1389
                                         9-0       0                1390
                                                   A2               1391
                                                   9-2              1392
                                                   A1               1393
                                                   9-1    0         1394
                                         9-1       0                1395
                                                   M1               1396
                                                   F3     0         1397
                                         9-2       0                1398
                                                   M10              1399
                                                   A20    0         1400
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IPL LIST

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P62 ATTACH SET MEM-SHIP TO CFO           P62       90               1401
                                                   P60    0         1402
                                         9-0       0                1403
                                                   A2               1404
                                                   9-2              1405
                                                   A1               1406
                                                   9-1    0         1407
                                         9-1       0                1408
                                                   M1               1409
                                                   F4     0         1410
                                         9-2       0                1411
                                                   M10              1412
                                                   A15    0         1413
P63 REMEMBER WORKING HYP                 P63       90               1414
                                                   P60    0         1415
                                         9-0       0                1416
                                                   A2               1417
                                                   9-2              1418
                                                   A1               1419
                                                   9-1    0         1420
                                         9-1       0                1421
                                                   M1               1422
                                                   F3     0         1423
                                         9-2       0                1424
                                                   M10              1425
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                                                  A18     0          1426
    P64 REMEMBER HOW WH FORMED          P64       90                 1427
                                                  P60     0          1428
                                        9-0       0                  1429
                                                  A2                 1430
                                                  9-2                1431
                                                  A1                 1432
                                                  9-1     0          1433
                                        9-1       0                  1434
                                                  M1                 1435
                                                  F4      0          1436
                                        9-2       0                  1437
                                                  M10                1438
                                                  A12     0          1439
    P65 REMEMBER OBJECT FOUND           P65       90                 1440
                                                  P60     0          1441
                                        9-0       0                  1442
                                                  A2                 1443
                                                  9-2                1444
                                                  A1                 1445
                                                  9-1     0          1446
                                        9-1       0                  1447
                                                  M1                 1448
                                                  F3      0          1449
                                        9-2       0                  1450


                IPL LIST

                                                  M10                1451
                                                  A16     0          1452
    P66 REMEMBER HOW OBJ FOUND          P66       90                 1453
                                                  P60     0          1454
                                        9-0       0                  1455
                                                  A2                 1456
                                                  9-2                1457
                                                  A1                 1458
                                                  9-1     0          1459
                                        9-1       0                  1460
                                                  M1                 1461
                                                  F4      0          1462
                                        9-2       0                  1463
                                                  M10                1464
                                                  A26     0          1465
    P67 REMEMBER CONCEPT                P67       90                 1466
                                                  P60     0          1467
                                        9-0       0                  1468
                                                  A2                 1469
                                                  9-2                1470
                                                  A1                 1471
                                                  9-1     0          1472
                                        9-1       0                  1473
                                                  M1                 1474
                                                  F3      0          1475
                                        9-2       0                  1476
                                                  M10                1477
                                                  A17     0          1478
    P68 REMEMBER HOW CONCEPT FORMED     P68       90                 1479
                                                  P60     0          1480
                                        9-0       0                  1481
                                                  A2                 1482
                                                  9-2                1483
                                                  A1                 1484
                                                  9-1     0          1485
                                        9-1       0                  1486
                                                  M1                 1487
                                                  F4      0          1488
                                        9-2       0                  1489
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                                              M10               1490
                                              A19      0        1491
P69 REMEMBER DESIGNATION OF CONCEP   P69      90                1492
                                              P60      0        1493
                                     9-0      0                 1494
                                              A2                1495
                                              9-2               1496
                                              A1                1497
                                              9-1      0        1498
                                     9-1      0                 1499
                                              M1                1500


               IPL LIST

                                              F4       0        1501
                                     9-2      0                 1502
                                              M10               1503
                                              A15      0        1504
P60 ATTACH (M1,X) TO V-LIST          P60      J52               1505
 OF CLASS ATT (2) OF (3)                      J81               1506
  (0) FX,(1)M1,(2)ATT,(3)M10                11W1                1507
                                            11W0                1508
                                              G12               1509
                                            11W2                1510
                                              J12      J32      1511
************************************1*****  ********            1512
C31 PUT COPY OF FOCUS AT TOP MEP     C31      90                1513
                                              P70      0        1514
                                     9-0      0                 1515
                                              A2                1516
                                              9-2               1517
                                              A1                1518
                                              9-1      0        1519
                                     9-1      0                 1520
                                              M1       0        1521
                                     9-2      0                 1522
                                              M10      0        1523
******'*****************************1*****  ********            1524
P71 NAME OF OBJECT TO E1             P71      90                1525
                                              P70      0        1526
                                     9-0      0                 1527
                                              A2                1528
                                              9-2               1529
                                              A1                1530
                                              9-1      0        1531
                                     9-1      0                 1532
                                              M10      0        1533
                                     9-2      0                 1534
                                              E1       0        1535
P72 NAME OF CONCEPT TO EXPERIMENTE   P72      90                1536
                                              P70      0        1537
                                     9-0      0                 1538
                                              A2                1539
                                              9-2               1540
                                              A1                1541
                                              9-1      0        1542
                                     9-1      0                 1543
                                              M10      0        1544
                                     9-2      0                 1545
                                              E1       0        1546
P70PUT FIRST SYMB FROM MEMORY        P70      J51               1547
  LIST ON A MEMORY LIST (OR E1)             11W1                1548
  INPUTS,, (0) MEM.LIST,(1) E1              11W0                1549
  GET OBJECT                                  G1                1550
```

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               IPL LIST

  PUT OBJECT ON MEMORY LIST                          G2     J31        1551
*************************************1 ***** ********                  1552
P501 RECALL SET MEMBERSHIP                 P501      90                1553
                                                     P500   0          1554
                                           9-0       0                 1555
                                                     A2                1556
                                                     9-2               1557
                                                     A1                1558
                                                     9-1    0          1559
                                           9-1       0                 1560
                                                     M10               1561
                                                     A15    0          1562
                                           9-2       0                 1563
                                                     M1     0          1564
P502 RECALL CONCEPT DESIGNATION            P502      90                1565
                                                     P500   0          1566
                                           9-0       0                 1567
                                                     A2                1568
                                                     9-2               1569
                                                     A1                1570
                                                     9-1    0          1571
                                           9-1       0                 1572
                                                     M10               1573
                                                     A12    0          1574
                                           9-2       0                 1575
                                                     M1     0          1576
P500 (M1,N)=MEP,(M1,D)=POT SYMB            P500       J51              1577
  OF V-LIST OF ATT (0) OF MEP                       40H0               1578
  (0) CLASS ATT (0), (1)MEP,(2)M1                     G30              1579
                                                    40H0               1580
                                                    11W1               1581
                                                      J81              1582
                                                    11W0               1583
                                                      G10              1584
                                                    70J31              1585
                                                      G2               1586
                                                    11W1               1587
                                                      J81              1588
                                                      G2     J31       1589
*************************************1 ***** ********                  1590
E93 DESIGNATE OBJECT                       E93        9-0              1591
                                                      E3     0         1592
                                           9-0        0                1593
                                                      A2               1594
                                                      9-2              1595
                                                      A1               1596
                                                      9-1    0         1597
                                           9-1        0                1598
                                                      E1     0         1599
                                           9-2        0                1600


               IPL LIST

                                                      M1     0         1601
  E3 DESIGNATE OBJECT                      E3         J51              1602
    CLEAR                                           11W1               1603
    M1                                                G30              1604
    (0) E1, (1) M1                                  11W0               1605
    GET OBJECT NAME FROM E1                           G1               1606
    DOUBLE NAMR IN H0                               40H0               1607
    ENTER CORRECT CONCEPT NAME                      11F5               1608
    TEST IF CONCEPT IN OBJECT                         R8               1609
    ENTER M1                                        11W1               1610
    GET RESULT OF TEST                                G8               1611
```

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                                                  J91              1612
                                                  J136             1613
    CCNSTRUCT                                   10A7               1614
    STM DESCRIPTION, PLACE                        U20              1615
    DESCRIPTION ON STM                            G2               1616
    PLACE OBJECT ON STM                         11W1               1617
                                                  J6               1618
                                                  G2      J31      1619
*************************************1  *****  ********            1620
C41 POP UP-MEP 1 LEVEL                  C41       90               1621
                                                  P400    0        1622
                                        9-0       0                1623
                                                  A1               1624
                                                  9-1     0        1625
                                        9-1       0                1626
                                                  M10     0        1627
P400 POP LIST                           P400    31H0      J8       1628
*************************************1  *****  ********            1629
P91 MAKE CONCLUSICNS ON DIM VALS        P96       90               1630
                                                  P95     0        1631
                                        9-0       0                1632
                                                  A2               1633
                                                  9-2              1634
                                                  A1               1635
                                                  9-1     0        1636
                                        9-1       0                1637
                                                  A7               1638
                                                  M10              1639
                                                  A12              1640
                                                  M1               1641
                                                  K96     0        1642
                                        9-2       0                1643
                                                  M1      0        1644
P95 MARK DIM VALS REL OR IRREL      1                              1645
    (0)K96,(1)M1,(2)A12,(3)MEP,(4)  M1                             1646
    SAVE INPUTS                         P95       J54              1647
    MAKE 99=0                                   5099               1648
                                                  J124             1649
                                                30H0               1650


                    IPL LIST

   GET OBJECT D                                11W1                1651
                                                  J82              1652
   GET E DESIG                                 11W4                1653
                                                  G10              1654
   SAVE                                        2097                1655
   GET WH                                      11W3                1656
                                                  J81              1657
   SAVE                                        6096                1658
   GET DIM VARIED D                            11W2                1659
                                                  G10              1660
   SAVE                                        6098                1661
   LIST                                        10A10               1662
                                                  J10              1663
   GENERATE BOTH                               1091                1664
   IN PARALLEL                                    J100    J34      1665
   DESCRIBE DIM AS REL,IRREL            91     1197                1666
                                               10A5                1667
                                                  J12              1668
   CHECK-IF DONE                               1099                1669
                                                  J125             1670
                                               11W0                1671
                                                  J114    J5       1672
                                        97        0       0        1673
                                        98        0       0        1674
                                        99     +01            0    1675
```

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*************************************1 ***** ********              1676
P91 MAKE CON3LUSICNS ON DIM VALS      P91       90                   1677
                                                P90    0             1678
                                      9-0       0                    1679
                                                A2                   1680
                                                9-2                  1681
                                                A1                   1682
                                                9-1    0             1683
                                      9-1       0                    1684
                                                A7                   1685
                                                M10                  1686
                                                A12                  1687
                                                M1                   1688
                                                K96    0             1689
                                      9-2       0                    1690
                                                M1     0             1691
P90  MARK DIMS AND DIM VALS REL OR 1 REL                             1692
  (0)K96,(1)M1,(2)A12,(3)MEP,(4)  M1                                 1693
  SAVE INPUTS                         P90       J54                  1694
  MAKE 99=0                                   5099                   1695
                                                J124                 1696
                                              30H0                   1697
  GET OBJECT D                                11W1                   1698
                                                J82                  1699
  GET E DESIG                                 11W4                   1700


                 IPL LIST

                                                G10                  1701
  SAVE                                        2097                   1702
  GET WH                                      11W3                   1703
                                                J81                  1704
  SAVE                                        6096                   1705
  GET DIM VARIED D                            11W2                   1706
                                                G10                  1707
  SAVE                                        6098                   1708
  GET DIM LIST CHANGED                        10A9                   1709
                                                J10                  1710
  GENERATE BOTH                               1091                   1711
                                                J100                 1712
  CLEAR MU1                                   11W1                   1713
                                                G30                  1714
  PUT DIM VARIED DES                          11W1                   1715
  IN M1                                       1198                   1716
                                                G2                   1717
  PUT WH IN M1                                11W1                   1718
                                              1196                   1719
  EXIT                                          G2     J34           1720
 91 SAVE DIM                           91     60W4                   1721
  CHECK ALL VALS MARKED                       10A5                   1722
                                                R41                  1723
                                              40H0                   1724
  CHECK IF ALL BUT 1 MARKED                     J60                  1725
                                                J78                  1726
  ERASE OUTPUT                                  J71                  1727
  NO EXIT                                     70       0             1728
  YES MARK DIM                                11W4                   1729
                                              1197                   1730
                                              10A5                   1731
                                                J12                  1732
  CHECK IF DONE                               1099                   1733
                                                J125                 1734
                                              11W0                   1735
                                                J114   J5            1736
                                       97       0      0             1737
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                                          98      0       0            1738
                                          99    +01              0     1739
 *************************************1 ***** ********                 1740
  P101 REMOVE IRREL DV                    P101     90                  1741
                                                   P100   0            1742
                                          90       0                   1743
                                                   A2                  1744
                                                   92                  1745
                                                   A1                  1746
                                                   91     0            1747
                                          91       0                   1748
                                                   M1     0            1749
                                          92       0                   1750


               IPL LIST

                                                   M1     0            1751
 P100 DELETE IRREL DV                     P100      J42                1752
   GET WH                                           J81                1753
                                                   20W2                1754
   GET DDL                                          J82                1755
                                                   60W1                1756
   GET CHANGE FROM LIST                            10A10               1757
                                                    J10                1758
                                                   70J32               1759
                                                   11W1                1760
   GET TO L                                        10A11               1761
                                                    J10                1762
   EXIT IF WRONG INFO                              70J32               1763
   GEN                                             1091                1764
                                                    R100               1765
   EXCHANGE FROM RTO                               11W1                1766
                                                   40H0                1767
                                                   40H0                1768
                                                   10A10               1769
                                                    J10                1770
                                                    J74                1771
                                                   11W1                1772
                                                   10A11               1773
                                                    J10                1774
                                                    J74                1775
                                                   10A10               1776
                                                    J11                1777
                                                   10A11               1778
                                                    J11     J32        1779
   SAVE DV (TO)                           91       20W0                1780
   CHECK REL,OIRREL                                10A5                1781
                                                    G10                1782
                                                   70J4                1783
   IRREL                                           10F1                1784
                                                    J2                 1785
   YES EXIT                                        70J4                1786
   IRREL,REMOVE FROM WH                            11W2                1787
                                                   11W0                1788
                                                    J69     J4         1789
 *************************************1 ***** ********                 1790
 P171 REVERT HYP BACK TO ORIGINAL         P171      9-0                1791
                                                    P170  0            1792
                                          9-0       0                  1793
                                                    A2                 1794
                                                    9-2                1795
                                                    A1                 1796
                                                    9-1   0            1797
                                          9-1       0                  1798
                                                    M1    0            1799
                                          9-2       0                  1800
               IPL LIST

                                                M1      0          1801
  P170 REVERT S.C. TO ORIGINAL STATE    P170    J42                1802
    GET                                         J81                1803
    S.C.                                       20W2                1804
    SAVE NAME M1                               60W0                1805
    GET S.C. FROM DES                           J82                1806
    GET LIST IOF CHANGED VALUES                60W1                1807
                                               10A11               1808
                                                J10                1809
                                               70J32               1810
    SAVE (TO) VAL LIST                         6097                1811
    CHANGE FROM LIST                           11W1                1812
                                               10A10               1813
                                                J10                1814
    SAVE (FROM) VAL LIST                       6098                1815
    GENERATE BOTH                              1091                1816
    IN PARALLEL                                 R100               1817
                                               11W1                1818
    COPY DDL                                    J74                1819
                                               60W1                1820
    EXCHANGE (FROM TO) VAL                     1197                1821
    COPY FROM LIST                              J74                1822
                                               10A10               1823
                                                J11                1824
                                               11W1                1825
                                               1198                1826
    COPY (TO) LIST                              J74                1827
                                               10A11               1828
                                                J11                1829
    CLEAR M1                                   11W0                1830
                                                G30                1831
    PUT DDL  IN M1                             11W0                1832
                                               11W1                1833
                                                G2                 1834
    PUT S.C. IN M1                             11W0                1835
                                               11W2                1836
                                                G2      J32        1837
    SUB PROCESS                         91      J51                1838
    REPLACE (TO VALUE)                         11W2                1839
    BY (FROM VALUE)                            11W1                1840
    ON SEARCH CRITERION                        11W0                1841
                                                J67                1842
                                                J4      J31        1843
  ************************************1 ***** ********             1844
  Q101 CAN CONCEPT BE GIVEN             Q101    90                 1845
                                                Q100    0          1846
                                        9-0     0                  1847
                                                A2                 1848
                                                9-2                1849
                                                A1                 1850


               IPL LIST

                                                9-1     0          1851
                                        9-1     0                  1852
                                                M10     0          1853
                                        9-2     0                  1854
                                                H5      0          1855
  Q100 CHECK IF ALL DIM VALS MARKED     Q100    J81                1856
    CHECK IF ALL DIM VALS MARKED               1091                1857
                                                J100    J8         1858
                                        91     10A5                1859
                                                G10                1860
                                               700      J8         1861
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************************************I ***** ********             1862
P121 FORM CONCEPT                       P121     9-0               1863
                                                 P120   0          1864
                                        9-0      0                 1865
                                                 A2                1866
                                                 9-2               1867
                                                 A1                1868
                                                 9-1    0          1869
                                        9-1      0                 1870
                                                 M10    0          1871
                                        9-2      0                 1872
                                                 M1     0          1873
P120 COLLECT CONCEPT (0)MEP,(1)M1       P120     J46               1874
  GET S.C.                                       J81               1875
  SAVE                                         20W6                1876
  SAVE M1                                      20W5                1877
  CONCEPT NAME                                   J90               1878
                                                 J136              1879
                                               20W3                1880
  DDL NODE                                       J90               1881
                                                 J136              1882
  SAVE                                         20W2                1883
  GENERATE S.C.                                11W6                1884
                                               1091                1885
                                                 J100              1886
  COPY S.C.                                    11W6                1887
                                                 R73               1888
                                               20W6                1889
  ATTACH COPY                                  11W2                1890
  TO DDL UNDER BASIS ATT                       11W6                1891
                                               10A31               1892
                                                 J12               1893
  CLEAR M1                                     11W5                1894
                                                 G30               1895
  PUT DDL IN M1                                11W5                1896
                                               11W2                1897
                                                 G2                1898
  PUT CONCEPT IN M1                            11W5                1899
                                               11W3                1900

                    IPL LIST

  EXIT                                           G2     J36        1901
  SUB P SAVE DIM VALUE                  91     60W4                1902
  CHECK IF REL,IRREL                           10A5                1903
                                                 G10               1904
  NIETHER,EXIT                                 70J4                1905
                                               20W1                1906
  PUT DIM VALUE                                11W2                1907
  ON DDL UNDER                                 11W4                1908
  REL OR IRREL ATT                             11W1                1909
                                                 J12               1910
  CHECK IF DIM VAL REL                         11W1                1911
  (REL) SYMB)                                  10F2                1912
                                                 J2                1913
  NO,EXIT                                      70J4                1914
  YES ADD TO                                   11W3                1915
  CONCEPT LIST                                 11W4                1916
                                                 J66    J4         1917
************************************I ***** ********             1918
E94 DESIGNATE CONCEPT                   E94      9-0               1919
                                                 E4     0          1920
                                        9-0      0                 1921
                                                 A2                1922
                                                 9-2               1923
                                                 A1                1924
                                                 9-1    0          1925
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                                          9-1       0                   1926
                                                    E1     0            1927
                                          9-2       0                   1928
                                                    M1     0            1929
   E4 EXPERIMENTER DESIGNATE CONCEPT      E4        J51                 1930
     CLEAR                                        11W1                  1931
     M1                                             G30                 1932
     (0) E1, (1) M1                               11W0                  1933
     GET SUBJECTS CONCEPT                           G1                  1934
     SAVE NAME                                    60W0                  1935
     PUT CONCEPT DESIGNATION ON                   11F5                  1936
     M1 COMPARE CONCEPT WITH                        R8                  1937
     CORRECT CONCEPT                              709-1                 1938
     COMPARE CORRECT CONCEPT WITH                 11F5                  1939
     SUBJECTS CONCEPT                             11W0                  1940
                                                    R8                  1941
     BUILD DETACHED DES.                  91        G8                  1942
                                                    J91                 1943
                                                    J136                1944
     SAVE H5                                      40H5                  1945
     CONCEPT DESIGNATION ATT.                     10A27                 1946
                                                    U20                 1947
     PUT DESCRIPTION                              11W1                  1948
     ON STM                                         J6                  1949
                                                    G2                  1950


                   IPL LIST

     PUT SUBJECTS                                 11W1                  1951
     CONCEPT ON                                   11W0                  1952
     STM                                            G2                  1953
                                                  30H5     J31          1954
   **************************************1 ***** ********               1955
   Q12 DETERMINE IF CONCEPT CORRECT       Q12       90                  1956
                                                    Q10    0            1957
                                          9-0       0                   1958
                                                    A2                  1959
                                                    9-2                 1960
                                                    A1                  1961
                                                    9-1    0            1962
                                          9-1       0                   1963
                                                    M1                  1964
                                                    A27                 1965
                                                    F1     0            1966
                                          9-2       0                   1967
                                                    H5     0            1968
   Q10 CHECK IF CONCEPT CORRECT           Q10       J51                 1969
     GET DES.                                       J82                 1970
     ENTER ATT                                    11W1                  1971
                                                    G10                 1972
     COMPARE                                      11W0                  1973
     EXIT                                           J2                  1974
                                                  30H0     J31          1975
   **************************************1 ***** ********               1976
   P181 ADD DIMENSION TO SEARCH C.        P181      90                  1977
                                                    P180   0            1978
                                          9-0       0                   1979
                                                    A2                  1980
                                                    9-2                 1981
                                                    A1                  1982
                                                    9-1    0            1983
                                          9-1       0                   1984
                                                    M1     0            1985
                                          9-2       0                   1986
                                                    M1     0            1987
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P180 ADD UNTESTED DV TO WH              P180     J47                 1988
  SAVE M1                                      20W7                  1989
  GET FOCUS COPY                                 J81                 1990
  GET WH OFF DES                               10A18                 1991
                                                 G10                 1992
  SAVE NAME                                    60W6                  1993
  PUT WH IN M1,N                                 G4                  1994
  GET DDL                                      11W7                  1995
                                                 J82                 1996
  GET (TO) LIST                                10A11                 1997
                                                 J10                 1998
  GENERATE                                     1091                  1999
                                                 J100   J37          2000


                 IPL LIST

  ADD (TO) LIST VALS TO WH              91     11W6                  2001
                                                 J6                  2002
                                                 J64    J4           2003
**************************************1 ***** ********               2004
R190 COPY FOCUS IN DAV ORDER            R190     J45                 2005
  SAVE                                         20W0                  2006
  SEARCH CRITERION                               J90                 2007
  SAVE NAME                                    20W2                  2008
  GET M13 PREF ORDER                           10A8                  2009
                                                 G10                 2010
                                               20W1                  2011
                                        93     11W2                  2012
  (FOCUS)                                      11W0                  2013
  (DIM LIST)                                   11W1                  2014
  SELECT DIM                                     R52                 2015
                                               7092                  2016
  GET COMMON VALUE ON FOCUS                      R1                  2017
  ADD TO COPY                                    J65    93           2018
  POP EXTRA SS                          92     30H0                  2019
  SET PROBS OF DIMS +                          12W1                  2020
                                        94       J60                 2021
                                                 J60                 2022
                                               7095                  2023
                                               12H0                  2024
                                                 J123                2025
                                                 J8     94           2026
                                        95     30H0     J35          2027
                                        97     +01           0       2028
**************************************1 ***** ********               2029
R52 SELECT PREFERRED DIM OF (0)         R52      J42                 2030
  SAVE LIST                                    60W0                  2031
  SELECT DIM                                     J16                 2032
  EXIT IF NONE                                 70J32                 2033
  SAVE DIM                                     20W1                  2034
  SET PROB                                     11W0                  2035
  OF DIM.                                      11W1                  2036
  OR DIM. VALUE MINUS                            G9                  2037
  RETURN WITH SELECTED DIM                     11W1     J32          2038
**************************************1 ***** ********               2039
Q41 FIND UNTESTED DIM(S)                Q41      90                  2040
                                                 Q40    0            2041
                                        9-0      0                   2042
                                                 A2                  2043
                                                 9-2                 2044
                                                 A1                  2045
                                                 9-1    0            2046
                                        9-1      0                   2047
                                                 M10                 2048
                                                 K97    0            2049
                                        9-2      0                   2050
```

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           IPL LIST
                                              M1                  2051
                                              H5      0           2052
Q40 FIND UNTESTED DIMS                Q40     J46                 2053
   SAVE (0) NO. OF DIMS TO FIND              20W1                 2054
   (1)MEP,(2)M1                               J81                 2055
   SAVE FOCUS COPY                           20W6                 2056
                                             30H0                 2057
   SAVE M1                                   60W5                 2058
   CLEAR M1                                   G30                 2059
   AND DIMS OF 1W1                           11W6                 2060
   HAVING PROPERTY A5                        10A5                 2061
                                              R40                 2062
   SAVE DDL                                  60W4                 2063
   DATA TERM                                 11W1                 2064
   CUT LIST                                   J200                2065
   ERASE REMAINS                              G30                 2066
   GET LIST OF CVALS                         11W4                 2067
   COLLECT DIMS                               R6                  2068
   MAKE DDL WITH DIMS                        10A9                 2069
                                              U20                 2070
   SAVE NAME                                 60W1                 2071
   PUT DIMS VALS                             11W4                 2072
   ON DDL                                    10A11                2073
   PUT DDL ON M1                              J11                 2074
                                             11W5                 2075
                                             11W1                 2076
   PUT DDL ON M1                              G2                  2077
   PUT FOCUS COPY ON M1                      11W5                 2078
                                             11W6                 2079
                                              G2      J36         2080
***********************************1 ***** ********               2081
Q42 FIND DIMS MARKED IRREL            Q42     90                  2082
                                              Q43     0           2083
                                      9-0     0                   2084
                                              A2                  2085
                                              9-2                 2086
                                              A1                  2087
                                              9-1     0           2088
                                      9-1     0                   2089
                                              M10                 2090
                                              K97     0           2091
                                      9-2     0                   2092
                                              M1                  2093
                                              H5      0           2094
Q43 FIND DIMS MARKED IRREL            Q43     J46                 2095
   SAVE (0) NO. OF DIMS TO FIND              20W1                 2096
   (1)MEP,(2)M1                               J81                 2097
   SAVE FOCUS COPY                           20W6                 2098
                                             30H0                 2099
   SAVE M1                                   60W5                 2100

           IPL LIST
   CLEAR M1                                   G30                 2101
   AND DIMS OF 1W1                           11W6                 2102
   VALUE                                     10F2                 2103
   HAVING PROPERTY A5                        10A5                 2104
                                              R42                 2105
   SAVE DDL                                  60W4                 2106
   DATA TERM                                 11W1                 2107
   CUT LIST                                   J200                2108
   ERASE REMAINS                              G30                 2109
   GET LIST OF CVALS                         11W4                 2110
   COLLECT DIMS                               R6                  2111
   MAKE DDL WITH DIMS                          10A9                2112
                                                 U20               2113
   SAVE NAME                                   60W1                2114
   PUT DIMS VALS                               11W4                2115
   ON DDL                                      10A11               2116
   PUT DDL ON M1                                 J11               2117
                                               11W5                2118
                                               11W1                2119
   PUT DDL CN M1                                 G2                2120
   PUT FOCUS COPY ON M1                        11W5                2121
                                               11W6                2122
                                                 G2       J36      2123
******'****************************1 ***** ********                2124
R81 FIND VAL OF ATT (0) OF LIST(1)     R81       J51               2125
   ATT(0) ASSUMED SPECIFIC                     11W1                2126
   GET VAL OR VAL LIST                 91      11W0                2127
                                                 J10               2128
   EXIT IF FOUND                               70         J31      2129
   NCT FOUND                                   11W0                2130
   GET  ATT (0) CLASS ATT                      10A6                2131
                                                 J10               2132
                                               70J31               2133
                                                 J81               2134
   GET SPECIFIC                                11W1                2135
   DESCRIPTION                                   J6                2136
                                                 G10               2137
                                               70J31               2138
                                               60W1       91       2139
******'****************************1 ***** ********                2140
R8I MAKE (1) A VAL OF ATT(0)           R82       J52               2141
   CN LIST (2)                                 11W0                2142
   ATT(0) ASSUMED SPECIFIC                     10A6                2143
   GET CLASS  ATT                                G10               2144
   NCNE,CONNECT SPEC                           7091                2145
   SAVE CLASS                                  2097                2146
   MAKE DDL                                    11W2                2147
   WITH CLASS ATT                                J90               2148
                                                 J136              2149
                                               60W2                2150


              IPL LIST


                                               1197                2151
                                                 J12               2152
   MAKE SPECIFIC                       91      11W2                2153
   DESCRIPTION                                 11W1                2154
                                               11W0                2155
                                                 J12      J32      2156
***********************************1 ***** ********                2157
R40 MAKE LIST OF ELEMENTS              R40       J90               2158
   OF L(1),HAVING ATT.(0)                        J136              2159
   SAVE OUTPUT AND ATT.                          J51               2160
   GENERATE L(1)                               1091                2161
                                                 J100              2162
   EXIT WITH OUTPUT IN H0                      11W0       J31      2163
   SUB P SAVE S                        91      6097                2164
   ENTER ATT.                                  11W1                2165
   CHECK IF ATT. ON DES OF S                     R81               2166
   NO,CONTINUE                                 70J4                2167
   YES, ADD S TO OUTPUT L                      51W0                2168
   AND CONTINUE                                11W0                2169
                                               1197       J65      2170
                                       97        0        0        2171
***********************************1 ***** ********                2172
R42 MAKE LIST OF ELEMENTS FROM L(2)    R42       J90               2173
   HAVING ATT (0) AND VAL (1)                    J52               2174
   GENERATE (2)                                1091                2175
```

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                                                   J100              2176
   RETURN WITH OUTPUTS                            11W0     J32       2177
   SAVE S                                  91     6097               2178
   CHECK FOR ATT (0)                              11W1               2179
                                                   G10               2180
   NO EXIT                                        70J4               2181
   YES ,CHECK VAL                                 11W2               2182
                                                   J2                2183
   NC,EXIT                                        70J4               2184
   YES ADD S TO OUT L                             11W0               2185
                                                  1197     J65       2186
                                           97       0      0         2187
*************************************1 ***** ********                2188
R41 MAKE LIST OF ELEMENTS                  R41     J90               2189
   OF L(1), NOT HAVING ATT.(0)                     J136              2190
   SAVE OUTPUT AND ATT.                            J51               2191
   GENERATE LIST (1)                              1091               2192
                                                   J100              2193
   EXIT WITH OUTPUT IN H0                         11W0     J31       2194
   SAVE S FROM L(1)                        91     6097               2195
     ENTER ATT (0)                                11W1               2196
   TEST IF ATT NOT ON DES OF S                     R81               2197
   YES CONTINUE                                   70       J8        2198
   NO,ADD S TO OUTPUT LIST                        11W0               2199
   ANC CONTINUE                                   1197               2200


                IPL LIST

                                                   J65     J4        2201
                                           97       0      0         2202
*************************************1 ***** ********                2203
R100 GENERATE SYMBS FROM                   R100   10W1               2204
   (1) AND (2) IN PARALLEL FOR (0)                 J17               2205
   SAVE LISTS (1),(2)                              J21               2206
   DOWN 1 ON (1)                           9-1    11W0               2207
                                                   J60               2208
                                                  20W0               2209
   EXIT IF END LIST                               70J19              2210
   DCWN 1 ON LIST (2)                             11W1               2211
                                                   J60               2212
                                                  20W1               2213
   EXIT IF END LIST                               70J19              2214
   ENTER SYMB FROM (2)                     95     12W1               2215
   ENTER SYMB FROM (1)                            12W0               2216
   EXECUTE SUB PROCESS                             J18               2217
   EXIT IF SUB-P RETURNS                          70J19    9-1       2218
U6 GEN PSEUDO PROGRAM                      U6     2099               2219
   STRUCTURE SYMBS FOR SUB P (0)                    91               2220
   POP INITIAL ENTRY                              3097               2221
   ERASE LIST OF SUB LISTS                        1098               2222
   (CANT BE USED IN RECURSIVE ROUTN)               J75     J71       2223
   PUSH LOC L                              91     4097               2224
   SAVE LOC                                       6097               2225
   ADD SUB L NAME                                 1098               2226
                                                   J6                2227
   TO LIST                                         J66               2228
   SCAN SUB LIST                           95     1197               2229
                                                   J60               2230
                                                  2097               2231
   IF END EXIT +                                  70J4               2232
   ENTER S TWICE                                  1297               2233
                                                  40H0               2234
   LOCAL                                           J132              2235
                                                  70       92        2236
   SET SIGN + BEFORE XEQ SUB P                     J4                2237
   NOT LOC PRESENT S TO SUB P                     0199               2238
   CCNTINUE OR QUIT                               700      95        2239
   SUB L, SEEN BEFORE                 92     1098                   2240
                                               J6                   2241
                                               J77                  2242
   IF SEEN GO TO 95 (CONTINUE)               70          95         2243
   NOT SEEN THEN GEN IT                      1297                   2244
                                               91                   2245
   EXIT TO POINT (POP LOC L)                 3097                   2246
   IF - EXIT AGAIN                           700         95         2247
                                      97      0         0           2248
   LIST OF USED LOCALS                98      0         0           2249
                                      99      0         0           2250


              IPL LIST

G11 (EQUIV TO J11 EXCEPT NO ERASE)    G11      J51                  2251
                                             52H0                   2252
                                             11W0                   2253
                                               J62                  2254
                                             7091                   2255
                                               J60                  2256
                                             20W0                   2257
                                             11W1                   2258
                                             21W0        J31        2259
                                      91     40H0                   2260
                                             11W0                   2261
                                               J65                  2262
                                             11W1                   2263
                                               J65       J31        2264
***********************************1 ***** ********                 2265
R6 COLLECT LIST OF (NEXT UPPERS)      R6       J90                  2266
  OF LIST (0)                                  J136                 2267
  SAVE NAME OF OUTPUT                          J50                  2268
  GENERATE LIST (0)                          1091                   2269
                                               J100                 2270
  EXIT WITH NAME OF OUT                      11W0        J30        2271
  SUB P  GET VAL OF SYMMETRY ATT.     91     10A6                   2272
  I.E. NEXT UPPER                              G10                  2273
  NCNE,CONTINUE                              70J4                   2274
  ADD IT TO OUTPUT LIST                      11W0                   2275
  ANC CONTINUE                                 J6        J65        2276
***********************************1 ***** ********                 2277
R73 COPY (C) WITHCUT ITS DESCRIPT     R73      J73                  2278
  MAKE OUTPUT NAME LOCAL                       J136                 2279
  SAVE NAME                                  6097                   2280
  BLCT OUT DES ON OUTPUT                     100                    2281
                                             2197       0           2282
                                      97       0        0           2283
***********************************1 ***** ********                 2284
R39 MAKE STRUCTURE (0) SYMMETRIC      R39    40H0                   2285
  DOUBLE LIST NAME,SAVE BOTH                   J51                  2286
  DCWN 1 ON LIST (0)                  91     11W0                   2287
                                               J60                  2288
                                             20W0                   2289
  EXIT IF END                                70J31                  2290
  ENTER SYM                                  12W0                   2291
  MAKE LIST NAME A VAL ON DES                11W1                   2292
  OF ITS SYMB                                10A6                   2293
  UNDER ATT A6                                 J12                  2294
  ENTER SYMB                                 12W0                   2295
  RECURSE AND CONTINUE                         R39       91         2296
***********************************1 ***** ********                 2297
R38 ERASE VAL LIST OF ATT.(0) ON (    R38      J50                  2298
  1) ,GENERATE (1)                           1091                   2299
  EXIT WHEN DONE                               J100      J30        2300
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                IPL LIST

   SUB P ,DOUBLE LIST NAME            91     40H0               2301
   ENTER ATT.                                11W0               2302
   DELETE ATT AND VAL FROM LIST                J14              2303
   ENTER ATT.                                11W0               2304
   RECURSE                                     R38    0         2305
*************************************1 ***** ********           2306
G210 IS DES OF (1) IN (2) UNDER CL    G210     J44              2307
    CLASS ATT                                20W1               2308
   SAVE (1) DES                              20W4               2309
                                             20W3               2310
   GEN SPEC ATTS OF CLASS ATT                11W1               2311
                                             1091               2312
                                               J100   J34       2313
   CCMPARE DESES                      91     20W2               2314
   GET VAL OF SPEC ATT FROMR1                11W4               2315
                                             11W2               2316
                                               G10              2317
   IF NONE CONTINUE                          70J5               2318
   GET VAL FROM ROUTINE 2                    11W3               2319
                                             11W2               2320
   CCMPARE THE TWO                             G10              2321
                                             70J8     J2        2322
*************************************1 ***** ********           2323
R3 (0)=(0)-(1) DIFFERENCE             R3       R73              2324
   DELETE SYMBS ON (0) FROM (1)              6097               2325
   COPY (0) SAVE NAME                          J6               2326
   GENERATE (1)                              1091     J100      2327
   DELETE S ON (1) FROM (0)           91     1197               2328
                                               J6               2329
                                               J69    J4        2330
                                      57       0      0         2331
*************************************1 ***** ********           2332
R4 MARK ELEMENTS OF L (2)             R4       J51              2333
   WITH ATT (0) AND VAL (1)                  1091               2334
                                               J100   J31       2335
   MARK GENERATED SYMBS WITH ATT      91     11W1               2336
   AND VAL                                   11W0     J12       2337
*************************************1 ***** ********           2338
R5 COPY LIST (1) AND CUT OFF          R5       J50              2339
   COPY AFTER (0)TH SYMB,OUTPUT COP            R73              2340
   SAVE COPY NAME IN H0                      40H0               2341
   LOCATE (0)TH S                            11W0               2342
   CUT,ERASE REMAINS                           J200             2343
                                               G30    J30       2344
*************************************1 ***** ********           2345
G1 FETCH 1ST LIST S OF LIST (0)       G1     40H5               2346
                                               J81              2347
   PCP H5 EXIT                               30H5     0         2348
*************************************1 ***** ********           2349
G4 INSERT                             G4       J51              2350
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                IPL LIST

   (0) IN FIRST LIST LOC                     11W1               2351
   OF (1) NO PUSH DOOWN               92       J60              2352
   IF EMPTY PUSH DOWN                        70       91        2353
                                             41H0     92        2354
                                      91     20W1               2355
                                             11W0               2356
                                             21W1     J31       2357
*************************************1 ***** ********           2358
G2 PUT (0) IN 1ST LIST POS. OF (1)    G2       J6               2359
   SAVE LIST NAME                              J50              2360
   SAFE H5                                   40H5               2361
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  PUSH DOWN LIST                             41W0             2362
  LOCATE 1ST POS                             11W0             2363
                                               J60            2364
                                             20W0             2365
                                             30H5             2366
  PUT S IN                                   21W0     J30     2367
************************************1 ***** ********          2368
G8 PICK YES,NO SYMBS VIA H5           G8     1091             2369
                                             70J82    J81     2370
                                      91       0              2371
                                               F1             2372
                                               F2     0       2373
************************************1 ***** ********          2374
G10 GET 1ST VAL OFF VAL LIST          G10      R81            2375
  OF ATT(0) OF LIST (1)                      700      J81     2376
************************************1 ***** ********          2377
G12 GET(M0,N),(M1,D) FROM (1)         G12    10F3             2378
  DEPENDING ON (0)                             J2             2379
                                             70J82    J81     2380
************************************1 ***** ********          2381
G9 SET VALUE OF ATT. (0) OF           G9       J10            2382
  LISTV (1) MINUS                            700              2383
                                               J123   J8      2384
************************************1 ***** ********          2385
R2 LOCATE LIST (0) EQUIVALENT         R2       J51            2386
  ON LIST CF LISTS (1)                91     11W1             2387
                                               J60            2388
  NEXT ON (1)                                20W1             2389
  END , QUIT                                 70J31            2390
  IS 1(1) EQUIV (0)                          12W1             2391
                                             11W0             2392
                                               R8             2393
  NO,CONTINUE SCAN                           7091             2394
  YES RETURN LOC.                            11W1     J31     2395
************************************1 ***** ********          2396
R8  (0) .C. (1)                       R8       J51            2397
  ENTER LIST (0)                             11W0             2398
  ENTER SUB P                                109-1            2399
  GENERATE AND TEST                            J100   J31     2400
```

IPL LIST

```
  SUB P  TEST IF S ON (1)             9-1    11W1             2401
                                               J6     J77     2402
************************************1 ***** ********          2403
R1 RETURN SYMB IF ON LISTS (0),(1)    R1       J51            2404
  ENTER LIST1                                11W1             2405
  SUBPROCESS                                 109-1            2406
  GENERATE LIST (1)                            J100           2407
  INVERT H5 AND EXIT                           J5     J31     2408
  DOUBLE SYMB FROM LIST (1)           9-1    40H0             2409
  ENTER LIST (0)                             11W0             2410
  INVERT ARGS                                  J6             2411
  SYMB (0) ON LIST (1)                         J77            2412
  REVERSE H5                                   J5             2413
  IF - FOUND, P CONTINUE                     700      J8      2414
************************************1 ***** ********          2415
U20 MAKE UP SPECIFIC                  U20      J51            2416
  ATT. DESCRIPTION LIST                        J90            2417
  (0) ATT., (1) VALUE                          J136           2418
  DOUBLE NAME                                40H0             2419
  OUTPUT (0) NAME OF DESCRIPTION             11W1             2420
                                             11W0             2421
                                               J11    J31     2422
************************************1 ***** ********          2423
G30 ERASE BODY OF LIST (0)            G30      J75    J71     2424
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************************************1 ***** ********                    2425
EXPERIMENTERS INST TO SUBJECT           L60     0                       2426
                                                L41                     2427
                                                L42                     2428
                                                L43                     2429
                                                L44                     2430
                                                L45                     2431
                                                L46                     2432
                                                L47                     2433
                                                L48                     2434
                                                L49                     2435
                                                L50                     2436
                                                L51                     2437
                                                L52     0               2438
************************************1 ***** ********                    2439
   PROBLEM DETAILS                      L41     90                      2440
                                                94      0               2441
                                        90      0                       2442
   MESSAGE TYPE                                 A60                     2443
                                                920                     2444
                                                A66                     2445
                                                L9      0               2446
   DDL CONTAINING MESSAGE               94      95      0               2447
                                        95      0                       2448
   FIRST PRCB FLAG                              A65                     2449
                                                F1                      2450


               IPL LIST

   EXTERNAL ENVIRONMENT                         A61                     2451
                                                921                     2452
   STRUCTRUE OF ENVIORNMENT                     A50                     2453
                                                922                     2454
   TYPE OF CON35PT                              A63                     2455
                                                923                     2456
   GCAL                                         A64                     2457
A11 CIM VALUE (TO8                      A11     Z                       2458
                                                924     0               2459
                                        920     0                       2460
     PROBLEM DETAILS                            F61     0               2461
                                        921     0                       2462
                                                E0                      2463
                                        922     0                       2464
                                                M13     0               2465
                                        923     0                       2466
                                                F80     0               2467
                                        924     0                       2468
                                                F1      0               2469
    HIDDEN ASSUMPTIONS                  L9      926     0               2470
                                        926     0                       2471
   AWARE                                        A91                     2472
                                                91                      2473
   DIMENSIONS IN WH                             A93                     2474
                                                92                      2475
   DIMENSICNS ACTUALLY VARIEDL                  A94                     2476
                                                93      0               2477
                                        91      0                       2478
   AWARE                                        F7      0               2479
                                        92      0                       2480
                                                K99     0               2481
                                        93      0                       2482
                                                K98     0               2483
************************************1 ***** ********                    2484
   START BY SHOWING FOCUS CARD          L42     90                      2485
                                                94      0               2486
   DESCRIPTION OF PROCESS               90      0                       2487
   MESSAGE TYPE                                 A60                     2488
```

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                                            920      0          2489
    DDL CONTAINING MESSAGE          94      95       0          2490
                                    95      0                   2491
    TYPE OF PROC5SS                         A30                 2492
                                            96                  2493
    COMMUNICATION                           A31                 2494
                                            97                  2495
    INFORMATION CREATED                     A32                 2496
                                            98                  2497
    DESIGNATION INFO                        A33                 2498
                                            99       0          2499
    VALUE OF A30                    96      0                   2500


                  IPL LIST

       COING                                F30      0          2501
    VALUE OF A31                    97      0                   2502
       FROM EXTERNAL                        F41      0          2503
    VALUE OF A32                    98      0                   2504
       FOCUS OBJECT                         F51      0          2505
                                    99      0        0          2506
                                    920     0                   2507
       PROCESS SPEC                         F62      0          2508
 **********************************1 ***** ********             2509
    SELECT AN OBJECT                L43     90                  2510
                                            94       0          2511
    DESCRIPTION OF PROCESS          90      0                   2512
    MESSAGE TYPE                            A60                 2513
                                            920      0          2514
    DDL CONTAINING MESSAGE          94      95       0          2515
                                    95      0                   2516
    TYPE OF PROCESS                         A30                 2517
                                            96                  2518
    COMMUNICA3ION                           A31                 2519
                                            97                  2520
    INFORMATION CREATED                     A32                 2521
                                            98                  2522
    DESIGNATION INFO                        A33                 2523
                                            99       0          2524
    VALUE OF A30                    96      0                   2525
      COING                                 F30      0          2526
                                    97      0        0          2527
    VALUE OF A32                    98      0                   2528
      SEARCH CRITERION                      F52      0          2529
                                    99      0        0          2530
                                    920     0                   2531
      PROCESS SPEC                          F62      0          2532
 **********************************1 ***** ********             2533
    FRCM THE BOARD                  L44     90                  2534
                                            94       0          2535
    DESCRIPTION OF PROCESS          90      0                   2536
    MESSAGE TYPE                            A60                 2537
                                            920      0          2538
    DCL CONTAINING MESSAGE          94      95       0          2539
                                    95      0                   2540
    TYPE OF PROC5SS                         A30                 2541
                                            96                  2542
    CCMMUNICATION                           A31                 2543
                                            97                  2544
    INFORMATION CREATED                     A32                 2545
                                            98                  2546
    DESIGNATION INFO                        A33                 2547
                                            99       0          2548
    VALUE OF A30                    96      0                   2549
      COING                                 F30      0          2550
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              IPL LIST

   VALUE OF A31                         97      0               2551
     FROM EXTERNAL                              F41    0        2552
   VALUE OF A32                         98      0               2553
     OBJECT CHOICE                              F53    0        2554
                                        99      0      0        2555
                                        920     0               2556
     PROCESS SPEC                               F62    0        2557
*************************************1 ***** ********           2558
   WHICH WILL BE DESIGNATED             L45     90              2559
                                                94     0        2560
   DESCRIPTION OF PROCESS               9C      0               2561
   MESSAGE TYPE                                 A60             2562
                                                920    0        2563
   DDL CONTAINING MESSAGE               94      95     0        2564
                                        95      0               2565
   TYPE OF PROC5SS                              A30             2566
                                                96              2567
   COMMUNICATION                                A31             2568
                                                97              2569
   INFORMATION CREATED                          A32             2570
                                                98              2571
   DESIGNATION INFO                             A33             2572
                                                99     0        2573
   VALUE OF A30                         96      0               2574
     COING                                      F30    0        2575
   INTERN EXTERN COMMUMNE               97      0               2576
                                                F42    0        2577
   VALUE OF A32                         98      0               2578
     OBJECT CHOICE                              F53    0        2579
   VALUE OF A33                         99      0               2580
     OBJECT                                     F71    0        2581
                                        920     0               2582
     PROCESS SPEC                               F62    0        2583
*************************************1 ***** ********           2584
   BY YES OR NO                         L46     90              2585
                                                94     0        2586
                                        9C      0               2587
   MESSAGE TYPE                                 A60             2588
                                                920             2589
   DDL CONTAINING MESSAGE               94      95     0        2590
                                        95      0               2591
   DESIGNATION ATT.                             A7              2592
                                                931    0        2593
                                        920     0               2594
   ATT SPEC                                     F63    0        2595
                                        931     0               2596
   YES                                          F1              2597
   NO                                           F2     0        2598
*************************************1 ***** ********           2599
   WHEN YOU HAVE THE CONCEPT            L47     90              2600

              IPL LIST

                                                94     0        2601
   DESCRIPTION OF PROCESS               9C      0               2602
   MESSAGE TYPE                                 A60             2603
                                                920    0        2604
   DDL CONTAINING MESSAGE               94      95     0        2605
                                        95      0               2606
   TYPE OF PROC5SS                              A30             2607
                                                96              2608
   COMMUNICATION                                A31             2609
                                                97              2610
   INFORMATION CREATED                          A32             2611
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                                                      98                  2612
   DESIGNATION INFO                                   A33                 2613
                                                      99      0           2614
   VALUE OF A30                           96          0                   2615
     DECIDING                                         F31     0           2616
                                          97          0       0           2617
   VALUE OF A32                           98          0                   2618
     CONCEPT                                          F54     0           2619
                                          95          0       0           2620
                                          920         0                   2621
     PROCESS SPEC                                     F62     0           2622
***********************************1 ***** ********                       2623
   FORM THE CONCEPT                       L48         90                  2624
                                                      94      0           2625
   DESCRIPTION OF PROCESS                 90          0                   2626
   MESSAGE TYPE                                       A60                 2627
                                                      920     0           2628
   DDL CONTAINING MESSAGE                 94          95      0           2629
                                          95          0                   2630
   TYPE OF PROC5SS                                    A30                 2631
                                                      96                  2632
   COMMUNICATION                                      A31                 2633
                                                      97                  2634
   INFORMATION CREATED                                A32                 2635
                                                      98                  2636
   DESIGNATION INFO                                   A33                 2637
                                                      99      0           2638
   VALUE OF A30                           96          0                   2639
     DOING                                            F30     0           2640
                                          97          0       0           2641
   VALUE OF A32                           98          0                   2642
     CONCEPT                                          F54     0           2643
                                          95          0       0           2644
                                          920         0                   2645
     PROCESS SPEC                                     F62     0           2646
***********************************1 ***** ********                       2647
   WHICH WILL BE DESIGNATED               L49         90                  2648
                                                      94      0           2649
   DESCRIPTION OF PROCESS                 90          0                   2650


                 IPL LIST

   MESSAGE TYPE                                       A60                 2651
                                                      920     0           2652
   DDL CONTAINING MESSAGE                 94          95      0           2653
                                          95          0                   2654
   TYPE OF PROC5SS                                    A30                 2655
                                                      96                  2656
   COMMUNICATION                                      A31                 2657
                                                      97                  2658
   INFORMATION CREATED                                A32                 2659
                                                      98                  2660
   DESIGNATION INFO                                   A33                 2661
                                                      99      0           2662
   VALUE OF A30                           96          0                   2663
     DOING                                            F30     0           2664
   VALUE OF A31                           97          0                   2665
     BOTH                                             F42     0           2666
   VALUE OF A32                           98          0                   2667
     CONCEPT                                          F54     0           2668
   VALUE OF A33                           95          0                   2669
     CONCEPT                                          F72     0           2670
                                          920         0                   2671
     PROCESS SPEC                                     F62     0           2672
***********************************1 ***** ********                       2673
   YES OR NO                              L50         90                  2674
                                                      94      0           2675
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                                         90        0                    2676
    MESSAGE TYPE                                   A60                  2677
                                                   920     0            2678
    DDL CONTAINING MESSAGE               94        95      0            2679
                                         95        0                    2680
    EXP DESIGNATION OF CONCEPT                     A27                  2681
                                                   941     0            2682
                                         941       0                    2683
    YES                                            F1                   2684
    NO                                             F2      0            2685
                                         920       0                    2686
    ATT SPEC                                       F63     0            2687
***********************************1     *****  ********                2688
    IF THE CONCEPT IS CORRECT            L51       90                   2689
                                                   94      0            2690
    DESCRIPTION OF PROCESS               90        0                    2691
    MESSAGE TYPE                                   A60                  2692
                                                   920     0            2693
    DDL CONTAINING MESSAGE               94        95      0            2694
                                         95        0                    2695
    TYPE OF PROCESS                                A30                  2696
                                                   96                   2697
    COMMUNICATION                                  A31                  2698
                                                   97                   2699
    INFORMATION CREATED                            A32                  2700


               IPL LIST

                                                   98                   2701
     DESIGNATION INFO                              A33                  2702
                                                   99      0            2703
     VALUE OF A30                        96        0                    2704
       DECIDING                                    F31     0            2705
                                         97        0       0            2706
     VALUE OF A32                        98        0                    2707
       CONCEPT                                     F54     0            2708
     VALUE OF A33                        99        0                    2709
       CONCEPT                                     F72     0            2710
                                         920       0                    2711
       PROCESS SPEC                                F62     0            2712
***********************************1     *****  ********                2713
     THATS IT                            L52       90                   2714
                                                   94      0            2715
     DESCRIPTION OF PROCESS              90        0                    2716
     MESSAGE TYPE                                  A60                  2717
                                                   920     0            2718
     DDL CONTAINING MESSAGE              94        95      0            2719
                                                   95      0            2720
    MESSAGE TERMINATION                            A81                  2721
                                                   96      0            2722
                                         96        0                    2723
                                                   F65     0            2724
                                         920       0                    2725
       TERMINATION                                 F65     0            2726
***********************************1     *****  ********                2727
    A1 PROCESS INPUT                     A1        0       0            2728
    A2 PROCESS OUTPUT                    A2        0       0            2729
    A3 PROCESS DESCRIPT (CL) ATT.        A3        0                    2730
                                                   A30                  2731
                                                   A31                  2732
                                                   A32                  2733
                                                   A33     0            2734
    A4 HOW OBJ FOUND                     A4        0       0            2735
    A5 REL,IRREL                         A5        0       0            2736
    A6 (NEXT UPPER ) SYMMETRY            A6        0       0            2737
    A7 EXP DESIG OF CARD CHOICE          A7        90      0            2738
                                         90        0                    2739
```

```
                                                 A6                 2740
                                                 91      0          2741
                                         91      0                  2742
                                                 A15     0          2743
   A9 DIM VARIED ATT.                    A9      90      0          2744
                                         9C      0                  2745
                                                 A6                 2746
                                                 91      0          2747
                                         91      0                  2748
                                                 A12     0          2749
   A10 CIM VALUE FROM                    A10     90      0          2750

                 IPL LIST

                                         9C      0                  2751
                                                 A6                 2752
                                                 91      0          2753
                                         91      0                  2754
                                                 A12     0          2755
                                         9C      0                  2756
                                                 A6                 2757
                                                 91      0          2758
                                         91      0                  2759
                                                 A12     0          2760
   A12 CLASS ATT. S.C. FORMATION         A12     0                  2761
                                                 A9                 2762
                                                 A10                2763
                                                 A11     0          2764
   A15 SET MWMBERSHIP ATT. (CLASS)       A15     0       0          2765
   A16 CBJ FOUND                         A16     0       0          2766
   A17 CCNCEPT FOUND                     A17     0       0          2767
   A18 WORKING HYPOTHSIS                 A18     0       0          2768
   A19 CONCEPT (HCW FORMED)              A19     0       0          2769
   A20 L100 ,VAL IS FOCUS COPY           A20     0       0          2770
   A27 EXP DESIG CF CONCEPT              A27     90                 2771
                                         9C      0                  2772
                                                 A6                 2773
                                                 91      0          2774
                                         91      0                  2775
                                                 A15     0          2776
   A26 HOW OBJ FOUND                     A26     0       0          2777
   A29 BASIS FOR CONST. CONCEPT          A29     0       0          2778
   A30 PROCESS THYPE                     A30     0       0          2779
   A31 PROCESS COMMUNICATION             A31     0       0          2780
   A32 INFORMATION CREATED               A32     0       0          2781
   A33 CESIGNATION INFORMATION           A33     0       0          2782
   A50 E9 ATT VAL IS M13                 A50     0       0          2783
   A60 EXP MESSAGE TYPE                  A60     0       0          2784
   A61 EXTERNAL ENVIORNMENT              A61     0       0          2785
   A63 TYPE CF CONCEPT                   A63     0       0          2786
   A64 THE GOAL                          A64     0       0          2787
   A65 FIRST PROBLEM ATT,(VAL=F1)        A65     0       0          2788
   A66 HIDDN ASSUMPTN NOT KNO TO SUBJ    A66     0       0          2789
   A80 PROBLEM DETAIL SPECIFICATION      A80     0       0          2790
    A81 MESSAGE TERMINATION              A81     0       0          2791
   A91 ARARENESS ATTRIBUTE               A91     0       0          2792
   A93 CIMENSIONS IN WORK HYP            A93     0       0          2793
   A94 CIMENSIONS ACTUALLY VARED         A94     0       0          2794
   A111 POSSIBLE VALUES OF SPEC ATT      A111    0       0          2795
   A300 L100 TYPE VAL IS E9              A300    0       0          2796
   A302 L100 , VAL IS STRAT              A302    0       0          2797
   F1 YES, RELAVANT                      F1      0       0          2798
   F2 NO, IRRELAVANT                     F2      0       0          2799
   F3 FLAG (M1,D)                        F3      0       0          2800
```

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                    IPL LIST

    F4 FLAG (M1,N)                              F4      0      0          2801
    F5 CCNTAINS CONCEPT                         F5      0      0          2802
    F6 CONTAINS NAME FOCUS CARD                 F6      0      0          2803
    F7 AWARE                                    F7      0      0          2804
    F8 UNAWARE                                  F8      0      0          2805
    F30 COING                                   F30     0      0          2806
    F31 DECIDING                                F31     0      0          2807
    F32 CCNTEXTING                              F32     0      0          2808
    F40 TO EXTERNAL                             F40     0      0          2809
    F41 FROM EXTERNAL                           F41     0      0          2810
    F42 BOTH                                    F42     0      0          2811
    F51 FOCUS CBJECT                            F51     0      0          2812
    F52 S.C.                                    F52     0      0          2813
    F53 OBJECT CHOICE                           F53     0      0          2814
    F54 CCNCEPT                                 F54     0      0          2815
    F61 PROB LETAILS                            F61     0      0          2816
    F62 PROCESS SPEC                            F62     0      0          2817
    F63 ATTRIBUTE SPEC                          F63     0      0          2818
    F64 FOCUS SPEC                              F64     0      0          2819
    F65 TERMINATION                             F65     0      0          2820
    F71 DESIGNATE OBJ                           F71     0      0          2821
    F72 LESIGNATE CCNCEPY                       F72     0      0          2822
    F80 TYPE CF CONCEPT                         F80     0      0          2823
    LTM                                         M3      0                 2824
                                                        S2     0          2825
    *****'*******************************1 ***** ********                 2826
    N10 PROB E10                                N10    +01           50   2827
    N20 PROB E20                                N20    +01           50   2828
    N30 PROB E30                                N30    +01           50   2829
    N40 PROB E40                                N40    +01           50   2830
    N50 PROB E50                                N50    +01           50   2831
    N11 PROB E11                                N11    +01           50   2832
    N12 PROB E12                                N12    +01           50   2833
    N21 PROB E21                                N21    +01           50   2834
    N22 PROB E22                                N22    +01           50   2835
    N31 PROB E31                                N31    +01           50   2836
    N32 PROB E32                                N32    +01           50   2837
    N41 PROB E41                                N41    +01           50   2838
    N42 PROB E42                                N42    +01           50   2839
    N51 PROB E51                                N51    +01           50   2840
    N52 PROB E52                                N52    +01           50   2841
    *************************************1 ***** ********                 2842
    POSITIVE INTEGTAL CONSTANTS                 K1     +01            1   2843
                                                K2     +01            2   2844
                                                K3     +01            3   2845
                                                K4     +01            4   2846
                                                K5     +01            5   2847
                                                K6     +01            6   2848
                                                K7     +01            7   2849
                                                K8     +01            8   2850
```

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                    IPL LIST

                                                K9     +01            9   2851
                                                K10    +01           10   2852
                                                K96    +01            1   2853
    K97 NUM UNTESED DIM TO FIND Q40             K97    +01            1   2854
    K98 NUM DIM TO VARY IN P130                 K98    +01            1   2855
    K99 NUM DIM IN WH EST BY P190               K99    +01            5   2856
    *****'*******************************1 ***** ********                 2857
    ELEMENTS                                    E11       0      0        2858
                                                E12       0      0        2859
                                                E21       0      0        2860
                                                E22       0      0        2861
```

```
                                         E31      0      0           2862
                                         E32      0      0           2863
                                         E41      0      0           2864
                                         E42      0      0           2865
                                         E51      0      0           2866
                                         E52      0      0           2867
      ******'*****************************1 ***** ********           2868
      E1 SUBJECTS OUTPUT CHANNELTO EXP.  E1       0      0           2869
      M1 SHORT TERM MEMORY (STM)         M1       0      0           2870
      M10 MEMORY ENTRY POINT             M10      0      0           2871
      M13 DIMENSION LIST                 M13      9-1                2872
                                                  E10                2873
                                                  E20                2874
                                                  E30                2875
                                                  E40                2876
                                                  E50    0           2877
                                         9-1      0                  2878
                                                  A8                 2879
                                                  9-2    0           2880
                                         9-2      0                  2881
                                                  9-3    0           2882
                                         9-3      9-0    0           2883
      9-0 PREFERENCE ORDER OF DIMS       9-0      0                  2884
                                                  E10                2885
                                                  N10                2886
                                                  E20                2887
                                                  N20                2888
                                                  E30                2889
                                                  N30                2890
                                                  E40                2891
                                                  N40                2892
                                                  E50                2893
                                                  N50    0           2894
      ************************************1 ***** ********           2895
      E10 DIM VALUE LIST                 E10      9-1                2896
                                                  E11                2897
                                                  E12    0           2898
                                         9-1      0                  2899
                                                  A8                 2900


                 IPL LIST

                                                  92     0           2901
                                         92       0                  2902
                                                  93     0           2903
                                         93       9-0    0           2904
      9-0 DIM VALUE PREF. ORDER LIST     9-0      0                  2905
                                                  E11                2906
                                                  N11                2907
                                                  E12                2908
                                                  N12    0           2909
      ************************************1 ***** ********           2910
                                         E20      9-1                2911
                                                  E21                2912
                                                  E22    0           2913
                                         9-1      0                  2914
                                                  A8                 2915
                                                  92     0           2916
                                         92       0                  2917
                                                  93     0           2918
                                         93       9-0    0           2919
      9-0 DIM VALUE PREF. ORDER LIST     9-0      0                  2920
                                                  E21                2921
                                                  N21                2922
                                                  E22                2923
                                                  N22    0           2924
```

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***********************************1 ***** ********         2925
                                    E30      9-1            2926
                                             E31            2927
                                             E32   0        2928
                                    9-1      0              2929
                                             A8             2930
                                             92    0        2931
                                    92       0              2932
                                             93    0        2933
                                    93       9-0   0        2934
9-0 DIM VALUE PREF. ORDER LIST      9-0      0              2935
                                             E31            2936
                                             N31            2937
                                             E32            2938
                                             N32   0        2939
***********************************1 ***** ********         2940
                                    E40      9-1            2941
                                             E41            2942
                                             E42   0        2943
                                    9-1      0              2944
                                             A8             2945
                                             92    0        2946
                                    92       0              2947
                                             93    0        2948
                                    93       9-0   0        2949
9-0 DIM VALUE PREF. ORDER LIST      9-0      0              2950

              IPL LIST

                                             E41            2951
                                             N41            2952
                                             E42            2953
                                             N42   0        2954
***********************************1 ***** ********         2955
                                    E50      9-1            2956
                                             E51            2957
                                             E52   0        2958
                                    9-1      0              2959
                                             A8             2960
                                             92    0        2961
                                    92       0              2962
                                             93    0        2963
                                    93       9-0   0        2964
9-0 DIM VALUE PREF. ORDER LIST      9-0      0              2965
                                             E51            2966
                                             N51            2967
                                             E52            2968
                                             N52   0        2969
                                   5                        2970
                                   5          S1            2971
              IPL POST LIST

NAME      LOC.          REFERENCES

A1        2728       89   195   317   538   695   881  1141  1168  1194  1231  1269  1323
                   1357  1393  1406  1419  1432  1445  1458  1471  1484  1497  1518  1530
                   1541  1558  1570  1596  1624  1635  1682  1746  1796  1850  1868  1924
                   1961  1982  2045  2087

A2        2729       94   883  1143  1166  1192  1229  1267  1321  1355  1391  1404  1417
                   1430  1443  1456  1469  1482  1495  1516  1528  1539  1556  1568  1594
                   1633  1680  1744  1794  1848  1866  1922  1959  1980  2043  2085

A3        2730      141   282   308   462   472   516   558   623   726   754   778   806
                    833   858   922   952   976  1003  1029  1056  1090  1114

A4        2735

A5        2736      160   653   913  1242  1298  1667  1722  1731  1781  1859  1903  2061
                   2104

A6        2737       47   390   483   530   546   647  1180  1182  2131  2143  2272  2293
                   2740  2746  2752  2757  2773

A7        2738      576  1156  1614  1638  1685  2592

A8           0     1289  2009  2879  2900  2915  2930  2945  2960

A9        2744      711  1211  1250  1279  1709  2069  2112  2762

A10       2750     1215  1254  1283  1336  1662  1757  1769  1776  1813  1823  2763

A11       2458      715   901  1304  1340  1761  1773  1778  1808  1828  1997  2073  2116
                   2764

A12       2761      717  1376  1439  1574  1640  1687  2749  2755  2760

A15       2765      293  1413  1504  1562  2743  2776

A16       2766     1452

A17       2767     1478

A18       2768     1426  1991

A19       2769     1491

A20       2770     1400

A26       2777      898  1465

A27       2771      633  1946  1965  2681

A29       2778

              IPL POST LIST

NAME      LOC.          REFERENCES

A30       2779      404   426   732   760   784   812   839   864   928   958   982  1009
                   1035  1062  1096  1120  2492  2517  2541  2566  2607  2631  2655  2696
                   2731

A31       2780      371   734   762   786   814   841   866   930   960   984  1011  1037
                   1064  1098  1122  1892  2494  2519  2543  2568  2609  2633  2657  2698
                   2732
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A32     2781      382  736  764  788  816  843  868  932  962  986 1013 1039
                 1066 1100 1124 2496 2521 2545 2570 2611 2635 2659 2700 2733

A33     2782      376  738  766  790  818  845  870  934  964  988 1015 1041
                 1068 1102 1126 2498 2523 2547 2572 2613 2637 2661 2702 2734

A50     2783      234  245 2453

A60     2784      209  213 2443 2488 2513 2537 2562 2588 2603 2627 2651 2677
                 2692 2717

A61     2785     2451

A63     2786     2455

A64     2787     2457

A65     2788      181  252  337 2449

A66     2789     2445

A80     2790      249  334

A81     2791     2721

A91     2792      584  676 2472

A93     2793     2474

A94     2794     2476

A111    2795      299

A300    2796      241

A302    2797      261  275  329

C3       709      503  506  533  571  650

C8       691      687

C10      201      193

               IPL POST LIST

NAME    LOC.          REFERENCES

C11      192      186

C12      177      189

C13      205      203

C20      466      460

C21      459      449  482

C22      616      614

C23      613      457  646  688

C31     1513      493  723  751  830 1000 1087

C36      511      509
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C37      508       451   529
C38      535       455   545
C39      542       536
C41     1621       594   597   661   664   947  1079  1080
C50      229       221
C51      269       223
C52      285       225
C60      322       315   442
C61      314       188
C101     302       364
D        855       515   519
D1       973       124
D2      1052       130
D3      1111       134
D4       775       499   505
D40      798       776
                IPL POST LIST
NAME     LOC.          REFERENCES
E          0      1361  2463
E1      2869      1535  1546  1599  1927
E2      1149      1139
E3      1602      1592
E4      1930      1920
E10     2896      2873  2885
E11     2858      2897  2906
E12     2859      2898  2908
E20     2911      2874  2887
E21     2860      2912  2921
E22     2861      2913  2923
E30     2926      2875  2889
E31     2862      2927  2936
E32     2863      2928  2938
E40     2941      2876  2891
E41     2864      2942  2951
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E42      2865      2943  2953
E50      2956      2877  2893
E51      2866      2957  2966
E52      2867      2958  2968
E93      1591       919
E94      1919      1026
E95      1138       187
F1       2798       255   340   578   636  1153  1784  1966  2372  2450  2469  2597  2684

F2       2799       180  1912  2103  2373  2598  2685

              IPL POST LIST
NAME      LOC.          REFERENCES
F3       2800      1397  1423  1449  1475  2378
F4       2801      1410  1436  1462  1488  1501
F5       2802       145  1608  1936  1939
F6       2803       651   894  1146
F7       2804       586   678  2479
F8       2805
F30      2806       741   769   821   848   937   967  1018  1044  1105  2501  2526  2550
                   2575  2640  2664
F31      2807       407   429   793   873   991  1071  1129  2616  2705
F32      2808       465
F40      2809
F41      2810       743   850  2503  2552
F42      2811       539  1046  2577  2666
F51      2812       448   745   772   876  2505
F52      2813       824  1108  2529
F53      2814       450   454   796   852   941  2554  2579
F54      2815       456   994  1021  1048  1074  2619  2643  2668  2708
F61      2816       220  2461
F62      2817       222  2508  2532  2557  2583  2622  2646  2672  2712
F63      2818       224  2595  2687
F64      2819
F65      2820       226  2724  2726
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D00

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F71       2821      943   971  2581

F72       2822     1050  1076  2670  2710

F80       2823     2467

G1        2346     1177  1179  1202  1240  1331  1366  1550  1606  1934

             IPL POST LIST

NAME      LOC.          REFERENCES

G2        2359      265  1158  1161  1221  1223  1260  1262  1382  1386  1551  1586  1589
                   1616  1619  1717  1720  1834  1837  1898  1901  1950  1953  2077  2080
                   2120  2123

G4        2350      348  1187  1994

G8        2369     1611  1942

G9        2382     1293  2037

G10       2375      214   235   276   330   335   372   377   383   405   427   577   585
                    634   677   899   902  1181  1183  1290  1299  1377  1584  1654  1660
                   1701  1707  1782  1860  1904  1972  1992  2010  2137  2144  2180  2273
                   2317  2321

G11       2251      391

G12       2378     1509

G30       2424      150   152   478   522   552   642  1151  1218  1247  1257  1374  1579
                   1604  1714  1831  1895  1932  2059  2066  2101  2109  2344

G210      2307      309   473   517   555   624

K1        2843      590   683

K2        2844

K3        2845

K4        2846

K5        2847

K6        2848

K7        2849

K8        2850

K9        2851

K10       2852

K96       2853     1642  1689

K97       2854     2049  2091

K98       2855      589  1235  2483
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             IPL POST LIST

NAME      LOC.          REFERENCES

K99       2856      1198  2481

L9        2470       583   675  2446

L41       2440       178  2427

L42       2485      2428

L43       2510      2429

L44       2534      2430

L45       2559      2431

L46       2585      2432

L47       2600      2433

L48       2624      2434

L49       2648      2435

L50       2674      2436

L51       2689      2437

L52       2714      2438

L60       2426       154

M1        2870        77   151   153   166   198   631  1148  1171  1173  1200  1237  1272
                    1274  1326  1328  1363  1396  1409  1422  1435  1448  1461  1474  1487
                    1500  1521  1564  1576  1601  1641  1644  1688  1691  1749  1751  1799
                    1801  1873  1929  1964  1985  1987  2051  2093

M3        2824       170   266   320

M10       2871        80    82   149   195   263   273   321   541   886  1197  1234  1360
                    1399  1412  1425  1438  1451  1464  1477  1490  1503  1523  1533  1544
                    1561  1573  1627  1639  1686  1853  1871  2048  2090

M13       2872       139   159  2465

N10       2827      2886

N11       2832      2907

N12       2833      2909

N20       2828      2888

             IPL POST LIST

NAME      LOC.          REFERENCES

N21       2834      2922

N22       2835      2924

N30       2829      2890

N31       2836      2937
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N32       2837      2939
N40       2830      2892
N41       2838      2952
N42       2839      2954
N50       2831      2894
N51       2840      2967
N52       2841      2969
P20       1174      1164
P21       1163       721
P50       1364      1353
P51       1352       828
P60       1505      1389   1402   1415   1428   1441   1454   1467   1480   1493
P61       1388       722
P62       1401       724    920
P63       1414       490    750
P64       1427       496    673    752    804    950   1088
P65       1440       829
P66       1453       831
P67       1466       999
P68       1479      1001
P69       1492      1027

                    IPL POST LIST
NAME       LOC.           REFERENCES
P70       1547      1514   1526   1537
P71       1525       918
P72       1536      1025
P90       1694      1678
P91       1677       603    948
P95       1647      1631
P96       1630       600
P100      1752      1742
P101      1741       581
P120      1874      1864
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P121     1863      998
P130     1238     1227
P131     1226      801
P140     1275     1265
P141     1264      802
P150     1329     1319
P151     1318      803
P170     1802     1792
P171     1791      572    949
P180     1988     1978
P181     1977      670   1086
P190     1201     1190
P191     1189      487    749
P400     1628     1622
P500     1577     1554   1566

                 IPL POST LIST
NAME      LOC.           REFERENCES
P501     1553      946   1053
P502     1565      606
Q10      1969     1957
Q12      1956     1054
Q40      2053     2041
Q41      2040      656   1081
Q42      2082      658
Q43      2095     2083
Q50       889      879
Q51       878      524    856
Q100     1856     1846
Q101     1845      974
R        1134     1084
R1       2404     2017
R2       2386     1370
R3       2324      895    905
```

```
R4      2333
R5      2339
R6      2266      1210  1249  2068  2111
R8      2397      1609  1937  1941  2393
R38     2298       161  2305
R39     2285       140   142  2296
R40     2158      2062
R41     2189       654  1243  1723
R42     2173      2105

                IPL POST LIST
NAME     LOC.        REFERENCES
R52     2030      1295  2015
R73     2278      1203  1385  1888  2324  2340
R81     2125       914  2166  2197  2375
R82     2141
R100    2204      1286  1343  1765  1817
R190    2005      1185
S1       138
S2       114      2825
S3       185       156
U1        25       157   345   396   424   439
U2        89        45   106
U3        94        43   104
U4        99        56
U5        86        73
U6      2219       174   304   693
U20     2416       712  1157  1212  1251  1615  1947  2070  2113
X20      164       158
Z        720       115  2458
Z1       800       120
Z2       827       121
Z3       917       122
Z4       945       123   549
```

```
Z5        297        128
Z6       1078        133   622   639
Z7        748        116   471   475

                     IPL POST LIST
     NAME      LOC.          REFERENCES
     Z8       1024       129
END IPL POST LIST
```

APPENDIX C
NARRATIVE DESCRIPTION OF MARK IV, MOD 2

C11 Control Contexter Program is to decide what type of a message is coming in and assign it to the proper decoder. Receive message from experimenter (automatic copy of input) and save the message. Determine the message type and save its value. Use the value of the message type to select a proper contexter. Execute the selected contexter.

C50 Include problem details in dummy description list. (The message was a problem-detail type.) Save the message (automatic extract name of dummy description list from message list body) information. I shall *call* the problem ______. I shall call the external world ______. Describe the problem by my name for the external world. The structure of the relationship between dimension values and dimensions of the external world are given by M13. Describe my name for the external world by this structure. Describe the problem by the problem details which I had saved.

Is this the first problem solution attempt? If yes, I shall call my strategy ______. Describe the problem by the name of the strategy. If no, recall the name of the most recent strategy used (obtained from long-term memory). Describe the problem by the name of the strategy. Use the name of the problem as a memory tracer.

C51 The message is a doing type. Save the message information (automatic extraction of ddl from message body). Get the description of the problem which names my strategy. Create a name for this behavior. Describe the name by the message information. Add the name of this behavior to the strategy.

C52 The message is a designation type. Save the message information (automatic extraction of ddl from message). The possible values of the experimenter's designation replies will be yes or no. Add this information to my general store of information.

C60 Recall my most recent strategy and recall the skeleton outline of the current problem. Is this the first problem?

- No—execute the most recent strategy, then remember it.
- Yes—create a name for the new strategy and save the name.

Create linkage to beginning of this phase and save linkage. Now I must compare desired behavior with existing behavior and fill in the strategy. To do this I must (*Sub Process*).

Sub Process

Compare descriptions of behavior on skeleton strategy with existing behaviors. Can I find a match?

- No—error.
- Yes—save name of behavior, add name of this behavior to the new strategy list.

Does this behavior receive information from the external world?

- No—(Go to 9-4).
- Yes—Is external information a designation?
  - Yes—Determine type of designation.
  - No—Determine what type of external information is received.

Now that information type has been determined, I must get contexter for that type. Add name of contexter to the phase (automatic next upper linkage insertion). (Insertions of contexter implies end of phase so that the behavior can be executed.) Now

execute the behavior phase just created. Save results of decision (all phases end with a decision output of yes or no). Save name of phase just executed. Was the last behavior on the phase list a decision-type behavior?
No—Exit sub-process.
Yes—Link the no response to the first phase. Link the yes response to the correct phase. Create new yes link.
Was result a previous decision a
No—Execute phase linked to the No.
Yes—Exit from sub-process.

[9-4] Is behavior-type a decision?
No—Exit sub-process
Yes—Has phase already been executed?
[Note either a contexter or a decision, continue implies phase execution.]
No—(Go to phase execution).
Yes—Execute just the decision behavior, erase temporary storage.
Go to 9-16.

C20 Create Z7
Information has been received from the external world. I must save where I am in the problem sequence so that I can return to this point later. Is the next behavior in the plan described like a Z7 behavior?
Yes—Exit this contexter.
No—Create a name which is described the same as Z7.
Place this name in the saved problem sequence. Use name of the present contexter to get name of phase, save the name of the phase. Get name of Z7 behavior. Add behavior which creates a working hypothesis. Add behavior to remember the working hypothesis (P191). Add behavior which will trace working hypothesis (C31). Add behavior to remember how the working hypothesis was formed. Add a decision behavior which decides if I can proceed to the phase (D4). Describe the phase to show that Z7 has been added to the phase. Describe the phase to show that D4 has been added to the phase.

C36 Verify object choice.
Save where I am in the problem solution. Obtain next behavior in the sequence. Is it described as a D-type routine?
Yes—Exit contexter.
No—Create a name for a behavior which is described as a DO routine. Add the DO behavior to the phase list (automatic next upper added to DO). Describe the phase list by the addition of DO.

C38-9 Create reaction to object designation. Save where I am in the problem sequence. Save the current memory entry point. Use name of contexter to obtain name of phase. Save the phase name. Create and save name for a routine described the same as a Z4 routine. Is the next behavior in the solution sequence described the same as Z4?
Yes—Delete the matching name from the problem sequence.
No—Add symbol for Z4 behavior to the phase list.
Describe phase list by addition of Z4 behavior.
Get experiment's designation of the object choice. Was it designated a yes?
Yes—Establish a routine to remove irrelevant dimensions, as the appropriate behavior, save name, (Go to 9-4).
No—Establish a routine to revert dimensions as the appropriate behavior, save name.
Is the subject aware of dimension varied?
No—(Go to 9-4).
Yes—Was one dimension varied?
Yes—(Go to 9-4).
No—Add routine to retrace memory one level to the Z4 routine. Then exit contexter.

9-4 Add to Z4 a behavior to retrace memory one level. Add to Z4 a behavior to mark the dimension values. Add to Z4 a behavior to mark the dimensions. Add a routine to recall the experimenter's designation of the object. Add appropriate dimension handling routine to Z4. Exit contexter. [Note: This routine is not consistent with the other routines.]

[Note: The interpreter must check for contexter and if so will put C1A in (0), along with other inputs.]

C22 Set up reaction to concept designation.

Save where I am in the problem sequence, obtain the next behavior in the problem sequence and determine if its designation matches that of a Z6 behavior.

Yes—Delete behavior from problem sequence.
No—Obtain experimenter's designation of the concept.

If it is a

Yes—Exit from contexter.
No—Create a symbol described as a Z6 behavior.

Add new Z6 to the execution list. Use name of contexter to get name of phase.

Describe phase by addition of Z6 behavior. Get the focus object and determine if any unmarked dimensions exist.

Yes—Set to add routine to which finds unmarked dimensions.
No—Set to add routine which finds irrelevant dimensions.

Save name of appropriate routine. Add routine to Z6 which retraces memory one level (C41). Add routines to retrace memory one level. Add appropriate routine from above (Q41, Q42). Add routine to add dimension to working hypothesis. Add routine to Z6 which remembers modified working hypothesis. Is the subject aware?

Yes—Correct focus object dimensionality.
No—Set dimensionality to unity.

Set routines which add dimension to above dimensionality. Exit contexter.

Z0 Problem specification

P21—Copy focus.
P61—Remember copy of focus object.
P31—Put name of focus copy in MEP.
P62—Remember set membership of focus copy.

P21 Copy focus object.
Get the name of the focus object from working memory, save the name.

Get a dimension value, use dimension value to get dimension. Use dimension to get the list M13. Make a copy of focus object in DAV order (R190). Give this copy a name, place name in M1,N. Exit subroutine.

[Note 1. This should be mostly within the subject. I think we should change program so that *E* routine gives an undescribed focus with internal name so that subject does not have to copy it.]

[Note 2. This routine is really unnecessary if we implement Note 1.]

P60-1 Attach (M1,X) to value list of class attribute (2) of list (3) (0) = Flag.

Input M1, F3
Output M10, A220.

Note that whatever is named in contents of MEP gets described. Remember ______. The item of information in working memory is stored as a value if an attribute describing the symbol contained in the memory entry point.

C31 Trace
The name contained in working memory is placed in the memory entry point so that one can trace the problem path in memory.

P62 Remember ______. Remember that the focus object is a member of the set, i.e. the ddl in working memory is stored as the value of an attribute describing the focus object.

Z7 Create a working hypothesis

P191—Create working hypothesis from the copy of the focus object (CFO).
P63—Remember working hypothesis.
C31—Place WH in MEP.
P64—Remember how working hypothesis formed.

P191 Make a working hypothesis having K99 dimensions. If the subject is not aware, this is a subject characteristic routine which creates the WH.

If the subject is aware, this routine is a legal doing-type routine.

Get the focus object from MEP, create a copy. Remove those dimension values beyond the K99th. Find the dimensions corresponding to these dimension values. Create a description list containing these dimensions. Save the ddl. Attach the dimension values under a "from" attribute. Store ddl in M1, D. Store WH in M1, N. Exit subroutine.

P63 Remember working hypothesis.

C31 Place name of working hypothesis in memory entry point.

P64 Remember how working hypothesis formed.

Z1 Create search criterion.

- P131—Select dimensions to vary.
- P141—Select dimension values.
- P151—Vary dimension values.
- P64—Remember how working hypothesis was varied.

P131 Select dimensions to vary.

Get the name of the WH from working memory. Collect dimension values not designated and save this list. I will vary only *K98* of these so discard the rest.

Make a list of the dimensions corresponding to the dimension values. Create a ddl for the dimensions. Add the list of dimension values to the ddl under a "from" attribute. Put name of WH in M1, N. Put name of ddl in M1, D. Exit from routine.

P140 Find new dimension values.

Get the list in M1, D describing what to vary, and save its name. Obtain value of the "from" attribute. Obtain the dimensions attribute. Generate dimensions and their values in parallel.

Sub Process. I know the dimension to vary and its original value. Obtain list of dominance values for the dimension. Set probability of dimension value negative (ignore dominant attribute value of this dimension value). Choose most dominant dimension value. If none, exit. Save this dimension value. Check to see if it has been designated.

- Yes—Pick up another dimension value.
- No—Make this DV a value of the "to" attribute of the ddl saved earlier. Restore DAV values of the "from" and "to" dimension values (seems peculiar should bein Z6 problem clean-up). Exit sub process.

P151 Vary the dimensions of the working hypothesis. Save the name of the working hypothesis. Get the ddl containing the change information and save its name. Get the list of "from" dimension values. Get the list of "to" dimension values. Generate the "from" and "to" dimension values in parallel

Sub Process Get the name of WH, then replace "from" DV to the "to" DV

[Note: Contents of M1 before P151 were WH and ddl, P151 manipulates the contents of WH but does not replace the contents of M1. Perhaps we should standardize the end of a routine to fill M1,N, M1,D.

P64 Remember how WH modified. Describe working hypothesis by the "from-to" list.

Z2 Select an object.

- P51—Find object matching search criterion. [Note: the search criterion is the working hypothesis after a dimension has been varied.]
- P65—Remember the object.
- C31—Place name of object in MEP.
- P66—Remember how object found.

P51 Save the inputs. Get and save the name of the search criteria. Search the external environment for object matching the search criterion (K2). Save the name of the matching object. Get value of change attitude ("from-to" list). Place name of change list in M1,D. Place name of object found in M1,N. [Note: We may want to systematize this by always using ***name*** for those symbols going into M1,N and ***descriptions*** for those symbols going into M1,D.]

D0 Verify object choice
Q51

Q51 Check object choice.
Save inputs. Get name of object chosen. Recall the focus object. Make list of symbols. Determine which dimension values of the object are not on the focus object. Save name of this list. Get "from-to" list from the "how found" attribute. Get the value of the "to" attribute. Find which values the focus object and "to" list do not have in common. Generate these values.

Sub Process Check to see if dimension values are marked.

- No—Exit.
- Yes—Pop H0.

Set output of Q routine ±.

[Note: This program determines what focus object and card choice do not have in common. Then it checks to see that the non-common dimension values are not already marked relevant or irrelevant. If unmarked, this object is O.K.]

Z3 Experimenter designates object.
 P71—present object choice.
 E93—experimenter designation.
 P62—remember designation.

P71 Put name of object in the output channel. Save inputs (MEP, E1). Get name of object choice from MEP. Place name on output list E2.

E93 Experimenter checks to see if object choice contains concept, sets value of designation attribute yes or no and puts ddl in M1, D and name of object in M1, N.

P62 Remember experimenter's designation of the object.

Z4 React to object designation.
 P96—mark dimension values.
 P91—mark dimension
 C41—pop to WH
 P101 or P171—delete or revert dimensions of the working hypothesis.

P96 Mark dimension values.
Save inputs, set number of values to zero. Obtain experimenter's designation of the object and save it. Get the working hypothesis and save it. Get the value of the "from-to" attribute and save the description list. Get the "from" dimension list. Generate dimension value list.

Sub Process Make experimenter designation an attribute value of the relevancy attribute. Save all (K96) dimension values required. Reverse H5.

P91 Mark dimensions relevant-irrelevant. Save inputs. Get object description, get experimenter designation of the object choice and save it. Get the search criterion and save it. Get the "from-to" list of the search criterion. Get the dimension changed list and generate it.

Sub Process Save the dimension. Check to see if all but one dimension value marked.
 No—Exit.
 Yes—Mark the dimension with experimenter designation.
 Check if done K96 dimensions.
  Yes—Terminate sub process.
  No—Continue.
Place dimension varied description in M1,D, place WH in M1,N, exit routine.

P502 Recall set membership (should be 501). Get value of set membership attribute of symbol named in MEP. Save inputs, get first symbol in MEP. Get first value off value list of (MEP) under set membership attribute.
If none—exit.
Put value in M1,D.
Put symbol from MEP in M1,N.

[Note: The general routine underlying this is P500 which enables one to find the first value on the value list of attribute _____ of list _____. This is a very powerful routine which isn't used enough.]

P171 Revert working hypothesis back to original form. Get name in M1; get description. Obtain the value of the "to" attribute and save it. Obtain the value of the "from" attribute and save it. Generate both lists.

Sub Process Replace the "to" value on the search criterion by the "from" value.

Create a description; make old "from" list the value of the "to" attribute.

Make the old "to" list the value of the "from" attribute.

Hold description in working memory.

Hold search criterion in WM.

P101 Remove irrelevant dimension from WH. Get WH from working memory; get its description. Obtain the value of the "from" attribute and save it. Obtain the value of the "to" attribute, save it. Obtain value of dimension attribute and save it. Generate both lists.

Sub Process Save the dimension value from the "to" list. Determine if it is marked irrelevant.
 No—Exit sub process.
 Yes—Remove the corresponding "from" value of the working hypothesis.
Create a description, make old "to" list the value of the "from" attribute. Add old dimension list as value of dimension attribute.
Hold WH in M1,N.
Hold ddl in M1,D.
[Note: Perhaps the class attribute should be a varied attribute, "what," "from," "to" as the specific values.]

D1 Can concept be presented?
 Q101

Q101 Get name of working hypothesis. Generate body of WH.

Sub Process Get value of designation attribute of the dimension value.

If unmarked—exit.
If marked—to next dimension value.

If all dimension values marked, then concept can be presented.

Z5 Form a concept.

P121—Form concept.
P67—Remember concept.
C31—Transfer concept.
P68—Remember how formed.

P121 Form concept. Get the search criterion (WH) and save it. Create name of concept. Create descriptions of concept and save it. Generate body of working hypothesis. (Sub process)

Sub Process Save dimension value, determine if dimension is unmarked. If yes, exit. If no, save value of relevancy attribute and save dimension value. Was dimension value relevant?

If yes—add value to body of concept.
If no—exit sub process.

Make working hypothesis the value of the basis attribute of the ddl. Place description in M1,D, place concept in M1,N.

Z8 Have concept designated.

P72—Present concept to experimenter.
E94—Experimenter action.
P69—Remember designation.

[Note: P72 is definition of present verb.]

Z6 Corrective action:

C41—Pop SC to WH.
C41—Pop WH to CFO
Q41—Find untested dimensions (or Q42)
P181—Add dimension.
C31—Place working hypothesis name in MEP.
P64—Remember what added.

Q41 Find untested dimensions. Get and save copy of the focus object (in MEP). Make list of all dimension values of CFO not marked *DELETE* all but K97 of the symbols. Find dimension corresponding to unmarked dimension values. Create description. Make list of dimensions the value of the dimension attribute (what). Add list of unmarked dimension values as value of the "to" attribute of the ddl. Place name of CFO in M1,N. Place description in M1,D.

Q42 Same as Q41 except that R42 used instead of R41. R42 checks for match of both attribute and its value, hence to list irrelevant dimension values one needs attribute value.

P181 Add dimensions to SC (WH in M1,N, new DV list in M1,D). Get value of hypotheses attributes of CFO and save it (WH). Hold it in M1,N. Get the description, obtain the "to" list from the description. Generate symbols on "to" list.

Sub Process Add symbol on "to" list to the working hypotheses. Place working hypotheses in M1,N. Place description in M1,D.

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